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ARMED FORCES 2 CHEMICAL JOURNAL

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FRONT COVER
By CHARLES MENDEZ

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THE NAVY PROPELLANT RESEARCH PROGRAM

By IRVING SILVER

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THE NAVY RESEARCH effort in propellants as directed by the Bureau of Naval Weapons has the objectives of: (a) supporting such research which would lead to significant advances in technology and thus provide the necessary knowledge upon which the design and development of future missile systems would be based; (b) carrying out the necessary research to provide the solutions for problems growing out of the Navy's current motor developments. In the first instance, research is concerned with meeting those Naval requirements as they may develop in the next decade; in the latter, with the more immediate requirements associated with getting current motor developments into the Fleet.

The high performance Navy motors now reaching the fleet and those under development have been made possible by the advances in propellant and propulsion technology brought about largely by the supporting research effort of the Navy. The progression of improvements in propellant impulse, mechanical strength, and ballistic properties of propellants, igniter design, erosion resistant insulation and nozzles, and high strength-light weight cases are all factors which have made possible the design and fabrication of higher performing Navy missile systems.

Prohibits Long Count

The wide range of Naval and Marine applications imposes severe environmental requirements on Naval missile systems. Since the Navy demands instant readiness, a long count-down to firing as is typical of cryogenic liquid engines is prohibitive. Naval service demands high standards of storage and handling. Accidental motor firings in a ship's magazine must be controllable or serious ship damage may occur. Navy motors are designed to experience the wide ranges of temperatures almost anywhere in the world and still function as designed after a minimum of 3-5 years of storage. In addition, they must withstand rough mechanical handling and acceleration shocks from both ship and air-launched positions in perfect safety without any degradation of performance.

The total Navy research program is aimed at achieving the foregoing goals. Some of the more pertinent aspects of this program with particular reference to propellants will be discussed below:

SOLID PROPELLANTS:

Historically, the use of double-base propellants by the Navy in the rocket motors is an extension of gun propellants into new applications. Several Navy motors now in service and in development are based on the use of double-base propellants. Improvements in performance and ballistic and physical properties coupled with advances in processing technology have enabled this type of propellant to remain competitive with the more recently developed composite propellant types. The limitation of the size of extruded double-base grains has been largely overcome by the cast double-base process. The latter process is more amenable to the use of case-bonding as a means of achieving a more efficient volumetric loading of the motor chamber. More recently, other methods for the processing of double-base propellants have been explored. Cast alurry techniques similar



Rear Adm. P. D. Stroop, Chief of the Bureau of Naval Weapons.

to the direct addition and mixing of composite propellants have proved feasible for double-base propellants. In addition, continuous mixing methods which have been proven applicable to polyurethane composites are showing promise for the preparation of double-base propellants. These new and advanced processing procedures offer reduced cost and improved safety while retaining essentially equivalent ballistic and physical properties.

Double Base

The upgrading of double-base propellants and enhancement of its ballistic and physical properties have been the direct result of the concentrated research support the Navy has provided for this type of propellant. The use of ballistic modifiers in controlling burning rates and in producing plateau-propellants (constant burning rate vs. pressure changes) has been a significant development in double-base propellant technology. The addition of light metals and ammonium perchlorate has now given the double-bases an impulse performance capability comparable to, and in some instances greater than other propellant types. As new energetic fuels and oxidizers become available, the double-base energetic binder system is expected to form the basis for the development of advanced propellants through the introduction of these ingredients into the binder. The double-base propellants have a demonstrated capability for performance and the growth potential to meet many of our future requirements.

Although the Navy will continue to support research and development of double-base propellants, other propellant types are being continually studied to determine their characteristics and applicability to Navy require-

ments. In those applications where the most extreme temperature requirements need to be met for storage and operational conditions, such as in Marine Corps use or in the aircraft-launched missiles, the composite propellant types come closer to satisfying requirements than the double-base propellants. This fact is mainly due to the thermal stability of propellant binders such as the polyurethanes and polybutadiene and the maintenance of the inherent toughness and elasticity of these binders over the required temperature ranges. In the past, one of the chief limitations of polyurethanes has been the relatively high brittle point of the polymer and the attendant undesirable stiffening of the propellant at certain low temperatures. Research in polyurethane chemistry, largely sponsored by the Navy through contractors, has resulted in new polyurethane molecular structures inherently better capable of maintaining adequate physical properties at the low temperature extremes. Propellant formulations based on these new binder structures are now being employed in the development of several current Navy motors. Similarly, polybutadiene propellants, although not generally developed under Navy research, are beginning to be considered by the Navy because of their outstanding aging properties and physicals at very low temperatures.

Impulse Limits

Although a considerable degree of success has already been attained in the development of high performance propellants, the Navy is steadily moving in the direction of even higher performance propellants approaching the theoretical limits of specific impulse. For this purpose, the Advanced Research Projects Agency (ARPA), in conjunction with the Services is supporting major research efforts in the synthesis of new ingredients. The Navy monitors several of the ARPA supported contracts and through other Navy supported contractors and in-house laboratories attempts to characterize the pertinent properties of these new ingredients and to conduct the necessary research which would lead to the development of advanced propellants utilizing these ingredients.

The research program in new ingredient synthesis is preceded by extensive computer performance calculations. At nominal cost, it is possible to determine whether a proposed chemical compound has promise as a high energy ingredient. These calculations give theoretical performance in typical propellant systems and serve to provide guidance in the selection of promising avenues for further research. Currently, the major interest is in those chemical structures based on combinations of N, O, B or F which theoretically are capable of forming compositions of significantly higher energy content.

Serious Problems

This research effort is now resulting in many new ingredients of higher energy content. However, the proper utilization of some of these ingredients presents several serious problems which need solution. The greater reactivity of these ingredients and the attendant tendency of some toward greater sensitivity to impact or friction, degradation by moisture or heat, and their incompatibility with other ingredients require new techniques for their processing and handling. Encapsulation is an approach towards the solution of these problems which is receiving major attention today. The chemistry and physics of encapsulation, the development of new encapsulation coatings, and techniques of encapsulation and the incorporation of encapsulated ingredients into propellant compositions are all aspects of this problem. The objective is an encapsulated ingredient which is effectively impermeable to moisture and other atmospheric influences and must be unreactive with

Irving Silver, Branch Engineer, Missile Propulsion Branch, Bureau of Naval Weapons.



other propellant ingredients when stored for long periods of time.

Not all of the Navy effort in solid propellants is directed towards the development of higher impulse propellants. Other major problem areas exist which require concentrated attention. For example, concurrently, with propellant development, a strong research effort in rocket motor materials is being made to satisfy certain vital requirements. With the demand for missiles with increased speeds and ranges and pay-load carrying capacity, the development of structural materials for rocket motor cases of greater strength and lighter weight is one of the chief approaches for achieving higher mass ratios. The Navy rocket motor materials program has resulted in higher strength steels and glass reinforced plastic structures which are now being introduced into the more advanced Navy motors. Further improvements in strength, modulus and light weight and the development of more sophisticated procedures for case fabrication leading to greater reliability and reduced cost are being investigated.

Erosion Problems

The increase in combustion chamber temperature and high mass flow rates resulting from the use of more energetic propellants have imposed severe insulation and erosion problems on the rocket motor. As a result, the Navy has investigated a broad variety of material types for the purpose of better understanding their behavior under both simulated and actual rocket motor conditions and to further improve these materials for use in rockets. Significant developments in new materials in rubber, plastic composites, graphites, and refractories have resulted and these materials are now being designed into current Navy motors about to be introduced into the Fleet. Further investigation of these materials is being supported with the particular view of providing the necessary materials to meet the more vigorous operating conditions anticipated for motors using the more energetic propellants for the future.

Another significant problem worthy of mention in this article is combustion instability. This is the phenomenon in which an acoustic resonance effect is established within a solid rocket motor leading to pressure oscillations occurring over a wide range of frequencies. Under certain conditions dependent upon the propellant, its size, geometry and other related factors, the oscillation can be transformed into irregular burning resulting in large pressure rises exceeding the design strength of the case causing rupture and failure. This condition of combustion instability is relatively common and results frequently in serious delays in development time and

increase in development cost. Although some solutions are known and have been shown to be effective, the exact causes of this phenomenon are not yet completely understood. The Navy has maintained a strong research effort in this field for a number of years and more recently, has joined with the other Services and ARPA in supporting a coordinated effort to provide the basic knowledge to effect a solution to this problem.

LIQUID PROPELLANTS:

Up to this point very little reference has been made in this article to liquid propellants. The fact is that the Navy maintains and supports a strong effort in the research and development of liquid propellants and engines. Because of the Navy requirement for instant readiness, the Navy has in effect pioneered certain types of liquid engines which now have a demonstrated capability of meeting this requirement and in this respect are equivalent to solid motors.

These liquid systems are designed as storable engines and operate on the principle that certain liquid and oxidizers having suitable energy, and physical and thermal properties can be permanently housed in sealed compartments without deterioration and on the sudden application of pressure can be ejected into a combustion chamber where they can chemically react. Such engines have been developed and are capable of not only producing total impulses comparable to solid motors of equivalent weight and volume but can be stored and operated over wide temperature ranges. The advantages of these storable liquid engines derive from their inherent capability to operate at temperature extremes which solid motors only now do with great difficulty, the latter requiring the solution of critical problems in grain design and attachment and in the development of suitable mechanical strength properties of the propellant. In

addition, these engines do not produce smoky exhausts which is a distinct advantage in certain tactical operations.

Research

Current research work in liquids is concerned with upgrading the performance of storable liquid engines. For this purpose, work is being directed towards the synthesis and evaluation of denser and more energetic liquid propellants. Increased density is being achieved by the synthesis and selection of more dense fuels and oxidizers and through the addition of light metal additives. The synthesis of more energetic liquid propellants, as with solid propellants, is being concentrated in B, O, N and F compounds. Although the ARPA research program is basically aimed at advancing the energy levels of solid propellants, derivative benefits are expected in that liquid fuels and oxidizers will be prepared in the course of the synthetic program. The Navy is prepared to characterize the pertinent properties of such ingredients and to evaluate them in rocket motor firings. From this type of research support, it is anticipated that storable liquid engines will grow in performance and will be competitive with solids for many applications.

In addition to storable liquids the Navy has also sponsored research in monopropellants. Through this effort, a new class of monopropellants based on cyclic amine-nitrate complexes has been developed and evaluated. Densities and specific impulse values comparable to the current state of technology in solid propellants has been achieved. It is believed that further advances will be made through the synthesis of new ingredients growing out of the ARPA and other Service sponsored programs in this field. Liquid engines based on monopropellants

(Continued on page 35)



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*This advertisement appears in
Phytopathology—April, 1960*

GENERAL SCHRIEVER BECOMES BOSS OF MISSILE AND AIRCRAFT SYSTEMS

Air Force Names New Research and Logistic Commands

BOUNDARIES ARE BEGINNING to appear on the new frontier in the Defense Department as Secretary McNamara reorganized the Air Force to centralize ballistic missile programs and aircraft systems under the command of Lieut. Gen. Bernard A. Schriever.

The move followed Air Force studies to improve systems management and these changes were recommended by Air Force Secretary Eugene M. Zuckert and Air Force Chief of Staff, General Thomas D. White.

General Schriever's new command is the Air Force Systems Command. His old organization, the Air Research and Development Command, known throughout the military as ARDC, went out of business April 1.

All activities of acquisition and development of aircraft and missile systems, some formerly carried on by the Air Research and Development Command and the Air Materiel Command, are now in the Air Force Space Systems Command.

At the same time, the Office of Aerospace Research, commanded by Major Gen. Daniel E. Hooks was brought into being and will report directly to the Chief of Staff Air Force. This office is composed of former elements of ARDC, namely: the Aeronautical Research Laboratory at Wright-Patterson Air Force Base, and the Cambridge Research Laboratories at Hanscom Field.

The Air Force Logistics Command is a redesignation of the Air Materiel Command at Wright-Patterson Air Force Base, and is commanded by General Samuel E. Anderson. This Command operates and controls logistic support for the entire Air Force and operates a multi-billion dollar business.

Air Force Systems Command

General Schriever's new command is composed of four divisions, as follows:

1. The Ballistic Systems Division commanded by Maj. Gen. Thomas P. Gerrity. It is composed of elements of the former ARDC Ballistic Missile Division and the AMC Ballistic Missile Center and the Ballistic Missile Office of the Army Engineers, an Engineer Command to accomplish missile base construction for the Atlas, Titan and Minuteman.

Brigadier Gen. A. C. Welling, Army Corps of Engineers, has been named as Deputy for Site Activation in the Ballistic Systems Division. He is in charge of base design, construction, installation and checkout. At each operational location in the field, task forces of AMC were combined with detachments from ARDC and the Corps of Engineers.

2. The Space Systems Division commanded by Maj. Gen. Osmond J. Ritland. It is composed of the ARDC Ballistic Missile Division and the AMC Missile Center.

3. The Aeronautical Systems Division commanded by Maj. Gen. Waymond A. Davis. It combines the Wright-Patterson Development Division of ARDC and the Aeronautical Systems Center of AMC.

4. The Electronics Systems Division commanded by Maj. Gen. Kenneth P. Berquist. It combines the Command and Control Development Division of ARDC and



LIEUT. GEN. BERNARD A. SCHRIEVER, USAF
Commands Air Force Systems

the Electronic Systems Center of AMC. It is located at Hanscom Field near Boston.

The Air Force Logistic Command affords a maximum participation to the four divisions of the Air Force Systems Command throughout all phases of the systems purchasing and acquisition cycle. When the Air Force Systems Command does work for other commands or Services, representation from those commands or Services will be a part of the project.

Reorganization Pattern

Organization of the Air Force Systems Command and the Air Force Logistic Command is proceeding on the following pattern:

The Air Materiel Command and the Air Research and Development Command were discontinued 1 April. The Air Force Logistics Command (AFLC), the Office of Aerospace Research and the Air Force Systems Command (AFSC) were activated 1 April.

AMC System Centers were transferred to AFSC 1 April, and AMC Contract Management Regions will be transferred to AFSC 1 July. The Commanders of AMC and ARDC are to determine materiel and procurement functions of the AMC centers with related manpower and personnel that should be retained by AFLC. Personnel and organizational segments involved will be frozen pending final decision. AFLC will continue through 30 June 1961 to fund and administratively service those transferred to AFSC. In making transfers, any net increase of on-board strength (either military or civilian) required in the balance of this fiscal year to effect the transition must first have prior approval of the Chief of Staff.

Procurement authority previously delegated to Commander AMC new rests with Commander AFLC by delegation Hq USAF. Commander AFLC has delegated Commander AFSC procurement authority formerly held in the ARDC and AMC Centers. This is an interim action pending redelegation of procurement authority by USAF.



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UNITED STATES ARMY IN WORLD WAR II

Volume two—Chemical Warfare

BOOK REVIEW

By COLONEL RICHARD M. LEE

United States Army in World War II. The Technical Services. The Chemical Warfare Service: From Laboratory to Field; by Leo P. Brophy, Wyndham D. Miles, and Rexmond C. Cochrane. Office of the Chief of Military History, Department of the Army, Washington, D.C., 1961.

This volume by Doctors Leo P. Brophy, Wyndham D. Miles, and Rexmond C. Cochrane is a recent addition to the series UNITED STATES ARMY IN WORLD WAR II published by the Office of the Chief of Military History. It is the second of a projected three volume sub-series portraying the functions and activities of the Chemical Warfare Service (CWS) prior to and during the Second World War. The purpose of this volume is to relate the story of CWS research, development, and supply activities up through 1945.

While the book focused primarily on the World War II period, the Chemical Warfare Service (designated Chemical Corps after World War II) is traced from its beginnings at American University in 1917 through the lean peacetime years of unceasing experimentation amid intermittent struggles for survival to the period of sudden expansion and all-out effort which our World War II General Staff demanded from this smallest of the Technical Services. Of unique interest are the early chapters which trace the truly absorbing story of the course of CWS experimentation, successes, failures, and developments on each of the major toxic agents and the history of the devices for protection against them. Also of note is the attention paid to the gradual involvement and growing interest of the CWS in biological warfare research. While the biological and chemical agents, developed with such exacting care and stocked in quantity at home and abroad, were not used in World War II, a number of CWS weapons and munitions did see frequent and important usage in the fighting. Probably few of World War II's participants remember or ever knew, for example, that the flame throwers, incendiary bombs and rockets, the white phosphorus shells and smoke, which were commonplace on European and Asian battlefields and in the massive air assaults against Germany and Japan, were developed by the CWS, at times in spite of disinterest, active opposition, and repeated disappointments. Combat arms officers of post World War II vintage may be surprised to discover that the famous 4.2 mortar, a tried and trusted workhorse of the Korean War and today's Infantry Battle Group, originated on the drawing boards of the CWS and had a most active World War II record as a chemical weapon.

The General Staff officer or student at War College or Leavenworth level will probably find a great utility and more acute interest in the latter chapters of the book. Starting about midway in the text, the authors discuss CWS procurement and mobilization planning as World War II storm clouds gathered, the beginnings of industrial mobilization as the fiscal flood gates jarringly loose in 1940 and 1941, and finally the rush to the all-out procurement of more and more of everything to equip an army growing by the millions. Here the authors analyze and assess a new set of problems, those having to do with

Colonel Richard M. Lee, born January 17, 1918, at Moscow, Idaho, received his B.A. degree at the University of Maryland and subsequently a Masters degree in Public Affairs at Princeton University. He entered the Army in February 1942 and integrated into the Regular Army in 1946.

During World War II he served with the 89th Infantry Division and since that time has had assignments with the 83rd Infantry, the 9th Infantry and 1st Cavalry Divisions.

Among various staff assignments he has served International Branch G-3, Department of the Army, and recently in the Office of Chief of Staff, Department of the Army. At present, Colonel Lee commands the 1st Battle Group, 3d Infantry (The Old Guard), at Fort Myer, Virginia.

war-time abundance—the reverse of the shortages and deficiencies of pre-war years. These problems included those of estimating needs for a war-time demand which had no precedent, the sudden requirement for more and more storage and other facilities, the search for suitable contractors to produce immediately, when many of those previously counted on were pressed into higher priority work by the other Technical Services of the Navy, the complexities of war-time pricing and the need to develop a workable supply control program to locate, account for, and classify the mounting CWS tonnages which were pouring off production lines. The authors delineate other difficulties that developed, such as those having to do with the troublesome storage and transportation of toxic agents, and those associated with supplying the ports of embarkation and meeting the special frustrations of CWS Lend Lease, which incidentally went principally to Britain and the USSR.

In the final chapter on Industrial Demobilization in 1944-45 there occurs a thoughtful examination of an entirely different set of problems as the nation moved toward the victorious climax of the war. The authors review the belated recognition, perhaps less in the CWS than elsewhere, of the need for detailed demobilization planning and of a well-conceived and phased program for the termination of contracts, disposal of the millions of dollars worth of property, cutting the civilian payrolls, and the disposition of facilities—all in a minimum of time.

The authors' concluding thoughts are devoted to the recurring vicissitudes of organization. After five years of devoted service of first value to the country, the CWS discovered that the course had again run full cycle. In deliberations involving the organization of the post war army, the Army Service Forces advanced the old pressures to abolish the CWS. In his successful drive to retain the organizational integrity of the Chemical Warfare Service, Major General William N. Porter, its chief, emphasized as an over-riding reason that, in the absence of the singleness of purpose and interest exercised by the CWS in the chemical and biological field, new ideas inevitably would be suppressed or at best be impeded. To illustrate his point, he referred to the 4.2-inch mortar. "This war," he said, "would not have the mortar (4.2)—with its brilliant record—but for the advocacy of the Chemical Warfare Service."

(Continued on page 10)

DOW
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Dr. Leo P. Brophy holds an A.B. degree from Franklin and Marshall College and M.A. and Ph.D. degrees in history from Fordham University. After teaching history and sociology at Fordham and Seton Hall Universities, he joined the staff of the Chemical Corps Historical Office in 1945. He has specialized in administrative and logistic history. Since 1953 Doctor Brophy has served as Chief of the Chemical Corps Historical Office. He is co-author of *The Chemical Warfare Service: Organizing for War*.

In reviewing a book such as this, which covers in a most thorough and informative way the truly major peace and war-time achievements of the CWS, it is plainly insufficient to simply summarize its contents. Rather one feels compelled to mention at least a few of the points of real significance which should not pass unnoticed.

Among those is the remarkable fact that this small Technical Service, whose activities were generally anathema to the pre-war public, which faced chronic lack of political and fiscal support and recurring threats of dissolution during the pre-war years, should nonetheless deliberately and conscientiously persist on a lonely course of experimentation and planning which bore fruit of the utmost value during World War II; it is a further curious fact and indeed commentary on the course of human events that the guns were hardly silent before this achievement was forgotten and the cry was again raised to dismember the CWS and distribute its activities to other Technical Services.

The resourcefulness and ingenuity of both the CWS and associated private industry, when confronted with difficult technical and planning problems, deserves special note. The authors recite scores of instances of difficulties that were overcome by the CWS civil-military team in the development and procurement of various weapons, munitions, and agents. The number and variety of these ingenious devices and discoveries together with the wisdom of their adoption alone constitute powerful support for retention of an organization which has apparently proven so successful in promoting timely and original solutions to the problems of this special technical field.

From the account as a whole it is possible to draw the conclusion that the pre-war chemical warfare developments of each major World War belligerent were rather closely parallel. It is an interesting point that, working independently and surrounded by a veil of secrecy, each power apparently went through similar experimental processes and came surprisingly close to the conclusions reached by the others. With the exception of Germany, the belligerents brought into the war substantially the same gasses, munitions, and weapons. While there were



Dr. Rexmond C. Cochrane obtained a Ph.D. in English Literature from Columbia University and was a member of the Chemical Corps Historical Office from 1945 until 1948. After teaching at Indiana University and the University of Virginia, he returned to the Historical Office as a consultant historian. He is at present a Research Associate in the Department of History, University of Maryland.



Dr. Wyndham D. Miles has an M.S. degree in organic chemistry from the Pennsylvania State University and a Ph.D. in History of Science from Harvard. After working in industry as a research chemist, and teaching chemistry at the Pennsylvania State University, he joined the staff of the Chemical Corps Historical Office in 1953.

some variations in the relative excellence of weapons and material, it is apparent that Germany alone clearly outstripped the others in her unique discovery and production of nerve gasses, of which the other powers were oblivious. In retrospect however, with this one exception, it is comforting to note that the U.S. by the mid-term of the war was, compared to her adversaries, quite adequately prepared to wage gas warfare.

A further thought is perhaps relevant. Accelerated procurement and supply operations for two years before the actual shooting started in 1941 placed the CWS in a position to meet the demands of full scale conflict. Had this two year preparatory phase not occurred, the authors concede that the state of CWS preparedness "at the time of the outbreak of war would have indeed been tragic." This is a pertinent point to present-day military planners in view of the possibility and capability of a potential present-day enemy to initiate major hostilities either abroad or directly against this country without warning.

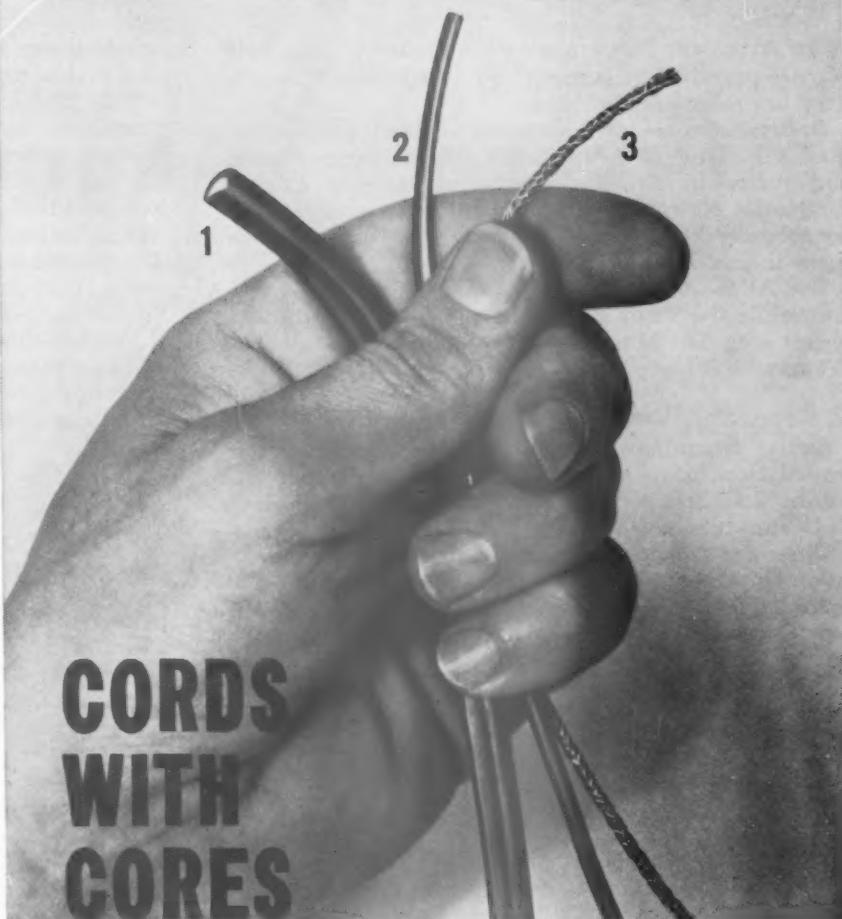
A final comment is due concerning the value and utility of this book. One cannot help applauding the painstaking care that has gone into its preparation, its obviously thorough treatment of a multitude of subjects, its well-conceived and comprehensive organization, and its presentation of a host of well-marshalled facts and accounts. Moreover, its simplicity and readability, rare qualities in a book of this sort, deserve high praise. Its pages are studded with such a wide variety of little known, interesting, and at times fascinating accounts that it can be read and enjoyed by members of the public unconnected with the uniformed services. The extraordinary case of the "Bat Bomb" experiment is an example. Primarily however, this book is of interest to and designed for military men—officers at DOD, or General Staff level, and students at the various Industrial and War colleges. It is to these men that the authors, I believe, have made a truly important, most useful, and lasting contribution in providing a rich background of past experience for those who may be called upon to face and resolve similar or even more critical security problems in the years ahead. It goes without saying that Chemical Corps personnel, military and civilian, will have a special interest in this book.

PEOPLE

William E. Vannah has been appointed associate for advanced engineering of The Foxboro Company, in Massachusetts. Mr. Vannah served in the U.S. Army Chemical Corps, in the South Pacific, during World War II. **Charles R. Plum** has been appointed Director of Marketing and Customer Services for Amcel Propulsion, Inc. **M. A. Weppner** has been elected president of Central Solvents and Chemicals Company. **Dr. Marshall C. Freerks** and **Dr. Lawrence J. Machlin**, both of St. Louis, have been promoted to Scientists with Monsanto Chemical Company. **C. E. Fittion, Jr.** has been named head of Thiokol Chemical Corporation's Advance Concept Analysis Group. **Robert E. Widing** is manager of manufacturing, a new position, for Pittsburgh Plate Glass Company's Chemical Division (formerly Columbia-Southern Chemical Corporation). **Dr. Wang Mo Wong** has joined the pilot plant research staff of U.S. Borax Research Corporation, Boron, Calif. **William T. Cave**, Dayton, Ohio, has been appointed assistant director of Monsanto Chemical Company's Research Center at St. Louis. **Dr. Leland I. Doan**, president of the Dow Chemical Company, was elected a director of the Bendix Corporation, at South Bend, Indiana. **James D. Moore** has been named Manager of Western Operations, for Vitro Chemical Company. **C. A. Bergman** has been appointed to the position of Market Manager—Chemicals, General Dystuff Company, Division of General Aniline & Film Corporation, New York. **Dr. William E. Thompson**, San Antonio, Texas, has been appointed director of research for Archer-Daniels-Midland Company. **James P. Barry**, Cleveland; **Martin H. Styles**, Philadelphia; and **C. Burton Wing**, Boston, are three new District Sales Managers appointed by the plastics Division of Allied Chemical. **Raymond Stevens** will serve as president and chief executive officer of Arthur D. Little, Inc. during the absence of **Lt. Gen. James M. Gavin**, recently appointed U.S. Ambassador to France. **Dr. William R. Nummy** has been appointed director of the Plastics Department research laboratories for The Dow Chemical Company.

Dr. Richard S. Turse has been appointed to the Research Department of Colgate Pharmaceutical Laboratories. **Dr. Nathan Marcuvitz** of Polytechnic Institute of Brooklyn, has been appointed vice-president for research. **Theodore H. Risch** has

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**WEAPON SYSTEMS
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BETTER THINGS FOR BETTER LIVING... THROUGH CHEMISTRY

(Continued on page 47)

BUILDING ICBM BASES POSES TOUGH PROBLEMS

THE ATLAS AND TITAN missiles are similar because both are propelled by burning liquid chemicals. It sounds easy but there are problems.

Both missiles are intercontinental and so is the Minuteman, a solid-fueled missile joining the hardware system, and all three have ranges described as classified but over 5,000 miles. Newspapers have reported, for example, that an Atlas fired from Cape Canaveral came back to earth in the Indian Ocean, some 9,000 miles distant.

The Atlas weighs 130 tons at take-off and is 82 feet long while the Titan is 110 tons of take-off weight and 90 feet long. The Minuteman is smaller, weighing about 35 tons with 60 feet of length and only six feet in diameter.

Missiles Above Ground

Earlier generations of missiles were based above the ground. Now, however, most of the bases under construction have launchers, service equipment, living quarters all located beneath the surface of the ground and some facilities are interconnected with tunnels and communication equipment. The silos which hold the "birds" are separated by more than a few miles and scattered over a wide area. Titan facilities at Lowry AFB in Colorado, for instance, scatter over more than 875 square miles.

The Ballistic Systems Division of the Air Force Systems Command, headed by Lieutenant General B. A. Schriever, has the responsibility for the design and construction of both the missiles and their bases. The newly created Ballistic Systems Division was composed of elements of the ARDC Ballistic Missile Office of the Army Corps of Engineers, in charge of missile base construction. Major General Thomas P. Gerry is the Commander of the Ballistic Systems Division and Brigadier General A. C. Welling, Army Corps of Engineers, is Deputy for Site Activation. General Gerry is responsible for development, test, evaluation, procurement, production, site activation and planning for the support and operation of ballistic missiles. General Welling will be in charge of facility design, construction, installation and checkout.

Oxidizes Kerosene

The Atlas missile is thrust into flight by liquid propellant rockets—two large boosters, one large sustainer, and a pair of small "vernier" rockets. All burn liquid oxygen and kerosene, and thrust is approximately 360,000 pounds. The missile travels at a speed of 15,000 miles per hour and later versions of the weapon are guided by an inertial guidance system so that once launched, they are independent of radio or other remote control.

Sixty feet of this missile is a tank of stainless steel, thinner than a dime, without internal framework, which must be kept under pressure to hold its shape.

Liquid oxygen goes into the upper portion of the tank and the kerosene goes into the lower—the two liquids being separated by a thin skin of metal. Liquid nitrogen is used as a coating agent for the liquid oxygen system and helium gas is the pressuring agent. As the liquids are burned up in flight the helium replaces them in the tanks to provide pressure and hold the missile's form.

Nuclear Warhead

The nuclear warhead is atop the tank structure and the rockets and guidance systems are after the tank.

In the silo, for the most advanced Atlas (the F model) the missile is its own storage tank for kerosene, military nomenclature—RP-1 fuel—with the RP standing for rocket propellant. However, storage of the liquid oxygen

inside the missile is impossible, and the oxygen loading is a part of the launching operation.

The silo which is a garage and filling station for the missile, is comparable to placing a 17-story building upright underground. It is built of reinforced concrete with an inside diameter of 52 feet. The walls are some nine feet thick at ground level and about 30 inches thick at the bottom of the shaft. Top of the silo is flush with the ground surface, and an overhead door assembly, weighing approximately 65 tons, seals off the entire silo against the possibility of a near miss by an enemy.

The two-story launch control center is attached to the silo by a passageway. This is where the maintenance and operating crews will have quarters. The control center is suspended in a shock mounted steel crib.

Missile Crib on Shocks

A large steel structure called the missile crib extends the entire depth of the silo and is suspended by air cylinder spring supports, or shock absorbers. The springs holding the crib carry a load of approximately 900 tons, including the weight of the missile. Within the silo both temperature and atmosphere are completely controlled, with the temperature always 72 degrees Fahrenheit.

There are eight floor levels in the crib. The base of the missile will rest on the sixth floor level and the levels below are filled with pumps, tanks, piping, valves, and controls which are integral parts of the propellant loading system. Floor levels are reached by an elevator or spiral staircase. The missile is raised and lowered on the launching platform.

Propellant Loading

The propellant loading system is the gas station to fuel the missile prior to flight. It consists of six prefabricated assemblies which contain controls, valves, pumps, instruments, pipes and cryogenic vessels, or enormous thermos bottles, which hold liquid oxygen and liquid nitrogen. There are, also, pressure vessels for holding gaseous oxygen, nitrogen and helium.

There are at least three tremendous problems in the design and manufacture of these systems. They are (1) the extremely high rate of flow required, reaching upwards of 5,000 gallons per minute; (2) low temperatures down to minus 300 degrees Fahrenheit, as oxygen liquifies at -273 degrees; and (3) rigid cleanliness requirements, for liquid oxygen explodes on contact with hydrocarbons and the mark made by a blunt pencil on a piece of paper could be enough to trigger an explosion.

Specifications permit maximum particle sizes of only 150 microns. The room in which the loading system components are cleaned and assembled, has the appearance of a massive hospital operating room. Workmen are required to wear nylon smocks, nylon caps, plastic gloves and plastic boots. The air in the room is filtered to 10 microns, and there are few hospital rooms that maintain more rigid cleanliness standards.

Pipes and Components

Stainless steel is used almost throughout the propellant loading system which has some 250 major components, such as valves, regulators, gauges and some 400 pipe assemblies. Extremely close precision is required in fabricating all of these components, due in part to the susceptibility of liquid oxygen to detonation from impact. Some of the nozzles carry operating pressures up to 6,000 pounds per square inch, and it is imperative that

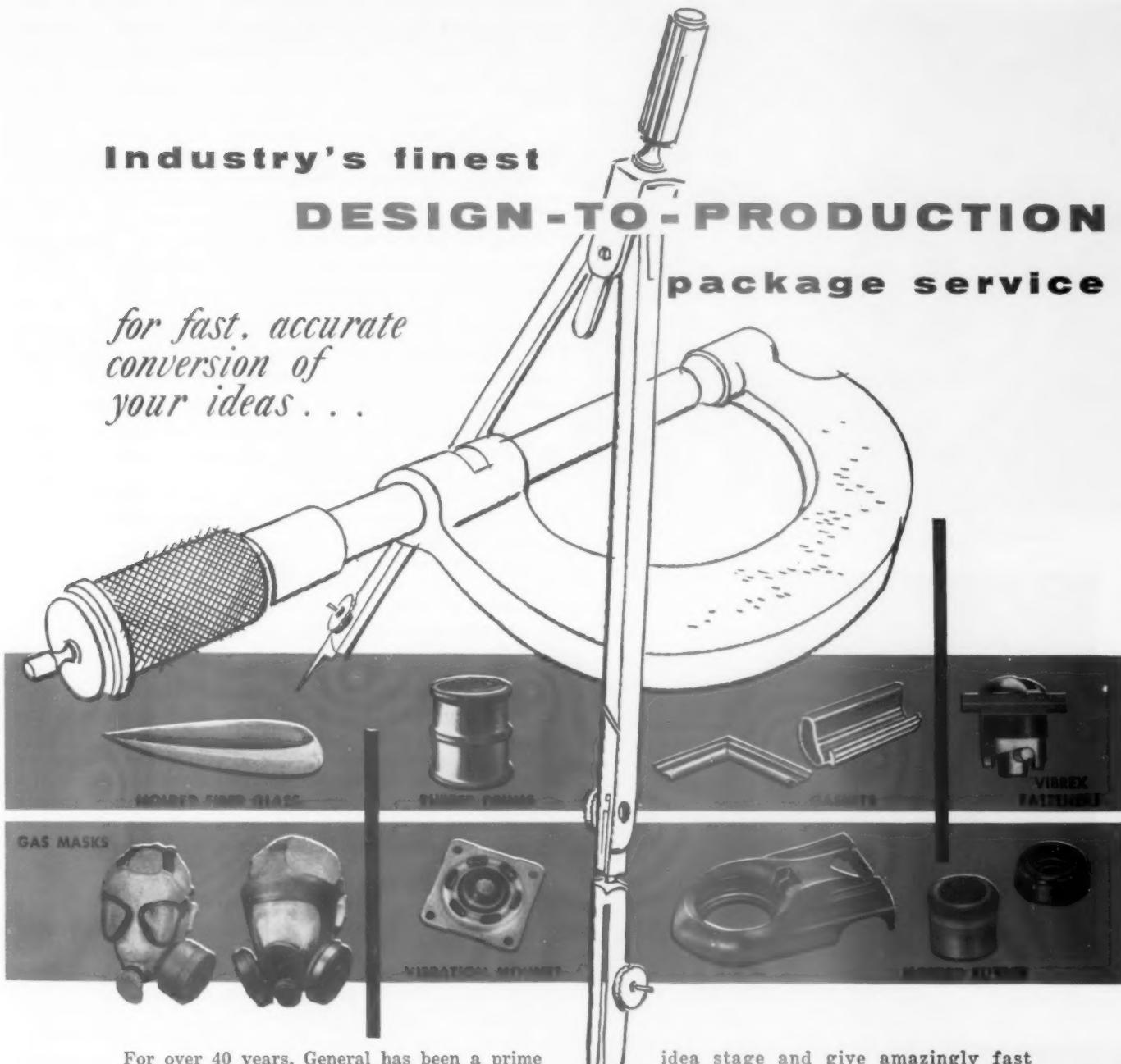
(Continued on page 14)

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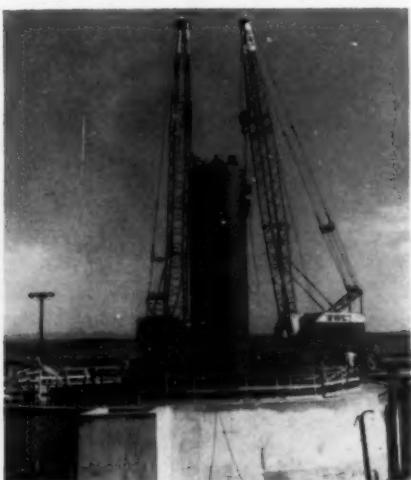
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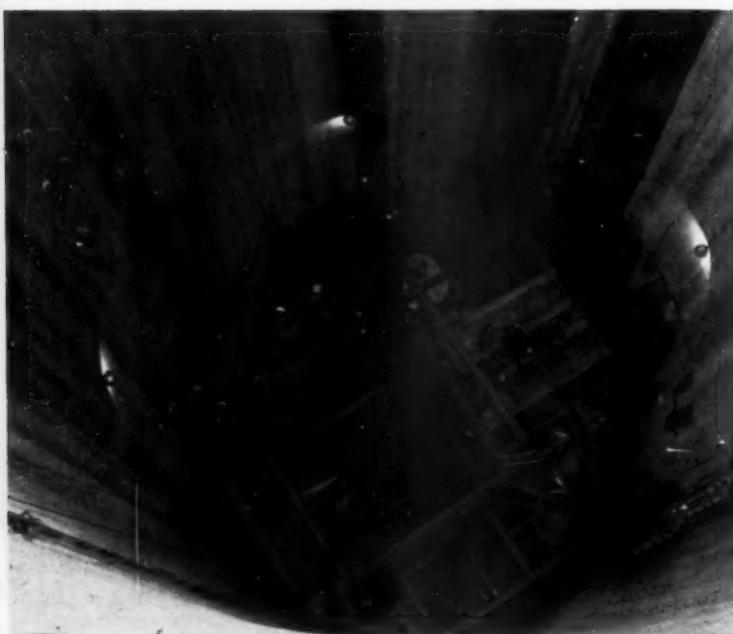


Construction of a missile silo and launch control center



Tank going into the silo

Fuel tanks in the silo



tiny particles of hydrocarbons are not allowed to pass and come into contact with the liquid oxygen. Leakage rates on some of the valves are measured in cubic centimeters per year, using helium gas, a very difficult gas to hold, as the testing agent. There are flexible hoses on which leakage through the wall of the hose, is measured.

One of the larger contracts on the propellant loading systems is held by the Paul Hardeman Company of Stanton, California. The components are prefabricated at the contractor's plant and charged with gaseous nitrogen and maintained under pressure until they are installed in the crib at the launching site. Every pipe assembly is cleaned and sealed to avoid contamination. As installation is started, each flange is bolted together under a polyethylene shroud, and constant purge of nitrogen gas is maintained. Use of welding equipment on the piping is not permitted during the installation. The system has to fit as it is fabricated, without changes.

Tests Outlet Valve

As to the magnitude of the propellant loading system, the largest valve—a 10-inch automatic operative valve—stands some eight feet tall. Two of the safety valves have a minimum flow requirement of 43,000 cubic feet per minute through a 6-inch opening. During the test of one of these valves, a fork-lift truck happened to be parked about 30 feet from the outlet of the valve. The force of the air coming from the valve rolled the truck over.

Another factor which brings problems into the construction of missile bases is the production and design of the missile—Atlas D, E, or F, or Titan I or II—has run concurrently with the design and construction of the bases. This means that any changes or advances in missile design has been reflected in change orders in the construction plans.

This concept of concurrency is pursued to shorten the time between conception and operational capability of a weapons system. By its very nature of procedure, change orders are necessary and these in turn are reflected in costs. However, this planning brings the weapon into operation by the quickest possible method.

Work Moves Ahead

Construction is going full blast on several dozen silos for Atlas "F" missiles, and has begun on three bases for Titan II and one Minuteman base. A number of Atlas squadrons have been completed and are operational.

Current ICBM construction programs involve work that will have a value of \$900 million. Since the construction of ICBM bases requires the contractor to assemble large amounts of equipment, supervisory personnel, highly skilled craftsmen and laborers, few individual concerns take on such a project alone. Many of these projects have been underwritten by combinations of large contractors or as joint ventures. Each contractor brings into the effort his organization's particular specialty.

Minuteman Base

The task of building bases for the Minuteman will be considerably less than for the Titan or the Atlas. Solid fuel propellants for the Minuteman eliminates the complicated structures and distribution systems required for liquid fuels used by the Atlas and Titan.

One of the Minuteman bases will be placed on the rolling stock of a railroad train and be able to fire wherever the train is, at the time the missile launch is desired.

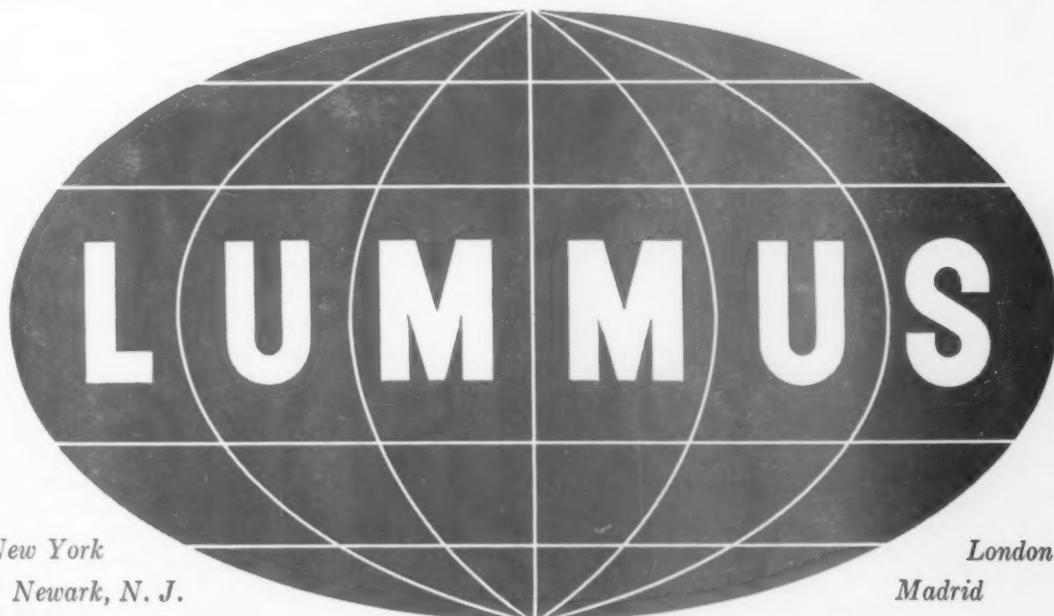
Permanent base construction is both a necessary and a big job, however, regardless of the type of missile involved. For example, 600 miles of travel are required

(Continued on page 16)

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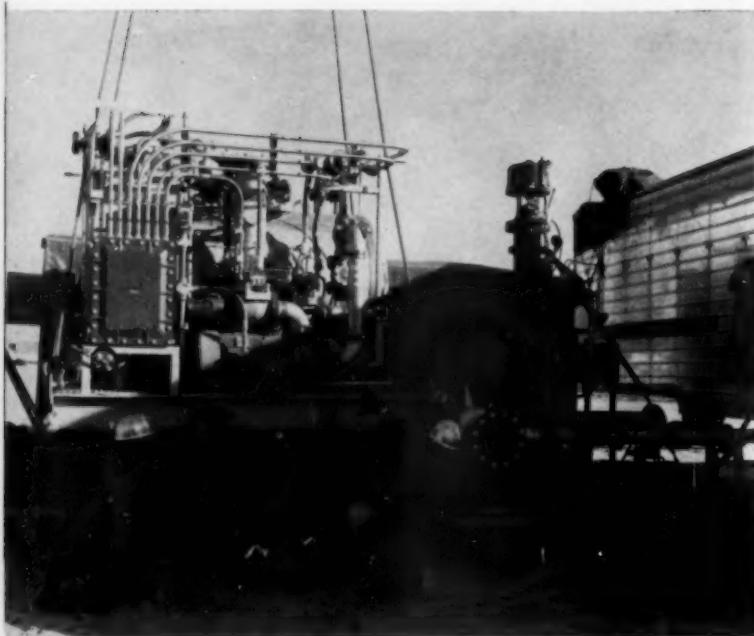
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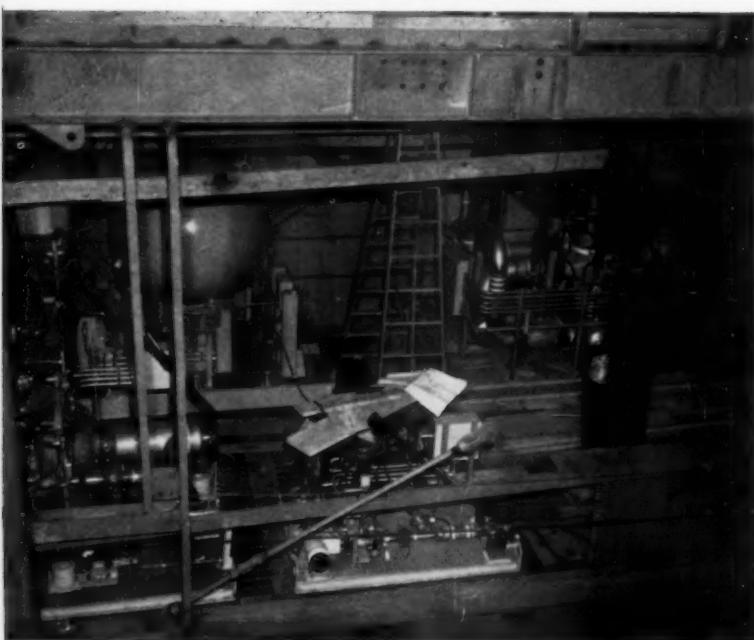


Chemical plant assembly



Installation on the LOX line

Seventh level of the silo



to cover all the Atlas sites at one installation now under construction, and 2,500 miles of right-of-way must be acquired for underground communications at the first Minuteman base in Montana.

Losses Overcome

Contractors working on construction of the ICBM bases have, in some cases, been faced with the specter of financial loss. This was particularly true at the start of the program rather than with more recent building efforts. This may be because everybody, Defense Department included, is gaining experience with a very difficult construction problem.

It must be remembered that the bases were—and are—being built concurrently with design and fabrication of the missiles. Any change in the missile requires a change in the base and, in addition, the contractor is meeting a time schedule so the base and missile will be completed at the same time. The contractor, to fill his schedule, has a flow plan for labor and material on the job. Throw a change order into the time schedule and almost anything can happen. It may put a premium price on everything in the pipeline by adding to costs one way or another. In other words, a change order can cause a plethora of things to happen, and most of them will cost money.

Charges for Changes

The contractor submits a claim for his estimates on the cost of the change or changes, and the government decides if these costs—in whole or in part—are chargeable to the changes.

It must be remembered, too, that these construction contracts are awarded on a lump sum low bid basis rather than cost plus fixed fee.

The Military Construction Subcommittee of the House Committee on Appropriations, U.S. Congress, made a report on Ballistic Missile Construction Program. Subcommittee Chairman Harry E. Sheppard (California) recommended some changes or "remedial" action in the ICBM program.

Operational necessity of the ballistic missile program, the subcommittee reported, has led the Air Force to insist on adherence to time schedules set forth in the contracts. This has magnified the complexity of properly costing these change orders, particularly with reference to their impact on the contractor's work schedule. A seeming inability has arisen, according to the report, to settle the cost of these change orders, in many instances.

Report Continues

The report continues "... division of responsibility within the Air Force, and between the Air Force and the Corps of Engineers, coupled with an abnormally large number of change orders and modifications and other problems, threatens to push costs to alarming proportions."

The Subcommittee recommends that an all-out effort be made to stabilize the design of the missile prior to the issuance of the construction contract for the base. Also, the Subcommittee points out that "the inadequate authority of the contracting officer to properly negotiate for the settlement of change orders" has been a drawback to the program. The Subcommittee believes that all functions of the ATLAS, TITAN, and MINUTEMAN should be placed under a single head responsible directly to the Chief of Staff and Secretary of the Air Force.

At the same time, the Subcommittee found satisfactory the method of contracting by awards to the low bidders.

The Congress has made a billion and one-half dollars available for this missile construction program. The 1962

(Continued on page 25)

NATIONAL PARKS READY FOR NATURE LOVERS

To tent and visit this summer

by CONRAD L. WIRTH

Director, National Park Service

The word "park" to the average person means a nearby area which has been solicitously landscaped, contains within its limited boundaries almost identical picnic grounds crowded near each other, and where the public may view caged or fenced-in wild animals.

The "National Park idea" is something entirely different. There, the landscaping is left to mother nature. She creates picturesque, aesthetic woodlands, grassy and flowery meadows, and rugged scenic wonders through which wild animals may be seen roaming at will. In national parks, picnic areas are located at sites where they do not intrude on surrounding park values, and, in many instances, nearby campgrounds beckon the nature lover.

The national park movement began some 90 years ago around a campfire in what is now Yellowstone National Park, Wyoming. There, in an atmosphere of high idealism, it was agreed that a place of such scenic and scientific wonder should be preserved for the joy and appreciation of all.

The ideals expressed at that memorable campfire have continued down through the years so that today the Nation has 186 areas in its National Park System. Not all of these contain geysers and thermal features, or the snow-capped mountains of Yellowstone, but in varied degrees they may contain canyons, lakes, streams, forested mountains, and places of historical renown. They are being preserved to serve as lasting sources of inspiration, education and enjoyment—not only for ourselves but also for future generations.

During 1960 more than 72,000,000 visits were recorded in areas of the National Park System. The principal attraction for these millions of visitors has been the outstanding scenery, geological and scientific wonders, and the desire to see and know their country—including its outstanding wonders—and to gain greater appreciation of its history.

We Americans are fortunate in the abundance of our national heritage, and especially in our marvelous national parks where increasing millions of people find recreation, pleasure and relaxation with economy. These

areas attract visitors from around the world who describe them as well deserving of everlasting preservation.

In 60 of the areas administered by the National Park Service there are more than 17,200 campsites and spaces located in 400 no-charge campgrounds and camp areas. These range in size from one-half-square-mile Timpanogos Cave National Monument in Utah, with two campgrounds and 26 campsites, to the 3,472-square-mile Yellowstone National Park, Wyoming-Montana-Idaho, with 25 campgrounds and 1,584 sites. In many of these areas, existing campgrounds are being expanded or new ones developed so that by 1966—it is anticipated—more than 30,000 campsites will be available to the public.

Camping is but one of the innumerable attractions offered in the National Park System. All of them have superlative features to offer, and camping simply provides a way for visitors and their families to enjoy these ideal vacation spots at a minimum of expense.

For example: Yellowstone National Park is without equal anywhere in the world. Its more than 10,000 thermal features, 200 geysers, myriads of hot springs, bubbling mud volcanoes, brilliant pools and terraces are more than enough to make it an unexcelled world attraction. But in addition, Yellowstone also contains the Grand Canyon of Yellowstone River with its 24 miles of sheer rock walls 1,200 feet deep, and 139-square-mile Yellowstone Lake, the largest body of water in America at so high (7,731 feet) an elevation.

On the West Coast, one of the principal points of interest is 760,951-acre Yosemite National Park in California. This area, in addition to containing 20 campgrounds with 3,666 campsites or spaces, is one of the most picturesque areas in the world.

The great naturalist, John Muir, in describing Yosemite wrote: "The most songful streams in the world . . . the noblest forests, the loftiest granite domes, the deepest ice-sculptured canyons . . . are found in Yosemite."

(Continued on page 44)

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THE CHEMISTRY OF THE MOON

By DR. H. C. UREY

*Institute of Technology and Engineering
University of California, La Jolla*

SOME WONDERFUL PHOTOGRAPHS of the moon have been taken in this century, but I believe very few of the physical scientists have paid much attention to them. Yet many wish to get photographs of the side we have not seen. Well, if it is not important to look at the front of the moon, why is it important to look at the back?

I think we can learn a great deal about the moon by looking at the front and, in fact, many attempts have been made to do this. However, I believe much of this work has not been very productive. It is because astronomers and others who have studied the moon are inclined to be polite. They are skeptical of what another man says, but they are much too polite to say so. So, all sorts of opposing views are put forward in print and no one tries to dispose of the worthless matter. No science can make much progress if it fails to do that. It is important to have new ideas, but it is equally important to eliminate the wrong ones we already have. I invite this elimination process in relation to what I will say and I shall practice it myself if I can.

Study Since the War

In the years since the war, we have been studying meteorites (which are extra-solar and extra-terrestrial in origin) and bringing together a considerable amount of information. A lot of this work was done by a group in Chicago, started by Harrison Brown. I continued it myself, at first because I thought it was a compliment to a former colleague to carry on his work, and later because I became immensely fascinated by it. Other work has been done abroad, in Washington, and elsewhere. As a result of all this, we have learned that meteorites are about 4½ billion years old. In addition, we have accumulated an enormous mass of chemical knowledge about them.

I published in the *Astrophysical Journal* an article on the origin of meteorites which stated approximately the following: early in the history of the solar system there accumulated objects of sufficient size so that pressures on their interior could produce diamonds, which are observed in meteorites. These must have accumulated and slowly cooled to temperatures in the neighborhood of 450 to 500 degrees in order to produce the two varieties of iron nickel that are observed in the chondritic meteorites; and then these objects were broken into very small bits and the material reaccumulated into secondary objects, which were the immediate ancestors of our chondritic meteorites. I call these the primary and secondary objects. Then, asking what was their size and density and so forth, I realized that the primary objects were exactly like the moon. Shortly after that paper was published I formed the opinion that the moon is a primary object, and that it was not broken up and captured by the earth during its growth. I still hold the view that this may account for the density and size of the moon, and I have yet to discover evidence to the contrary. I shall be very glad to see the data that will be accumulated on the chemistry and geology of the moon, and of course I expect to have a very red face in the course of a few years. Nature can always be more complicated than we imagine.

Now, we have some data about the chemistry of the moon. The first is its density—about 3.34 gram per cubic centimeter. This is a little high for silicates. However, if one takes the abundances of the elements in our tables at the present time, assumes that the iron is all oxidized, and makes up a set of appropriate minerals, he will find that the density for these materials comes somewhere near 3.47. This is somewhat higher than the density of the moon, but the interior of the moon has a higher temperature than the surface of the earth. The abundance of iron in the sun appears to be lower than what we have used for calculating this figure of 3.47, indicating that some fractionation of the elements has occurred, with an increased concentration of iron in all the meteorites. I am not sure that this conclusion is correct, but I must say that the content of iron observed in the sun at the present time and the amount of iron that is observed in our best sample of meteorites appears to differ by a factor of about 3 to 7, which is not small, as you see. From our knowledge of the abundance of elements, the moon may be a sample of the nonvolatile fraction of cosmic matter. There might be even a small amount of metallic iron in the moon; we cannot say from these density figures. The fact that the interior of the moon must be above ordinary terrestrial room temperature could account for the discrepancy between the calculated and the observed densities. I have attempted to estimate this temperature, and working back from this, I have calculated what the density of the moon would be at ordinary temperatures. I worked out at 3.45. All of these estimates in regard to density are uncertain, and we must be prepared to revise them as we gain more knowledge.

Moon Composition

So it appears that the composition of the moon as a whole is representative of primordial, nonvolatile fractions of cosmic matter. The earth, apparently, has a much increased concentration of metallic iron; Mercury has an even greater concentration; and Mars has somewhat less, Venus and the earth being much alike. This is the conclusion we reach from judging their densities and estimating the change of density with pressure on the interior of the object. Therefore, the moon is average cosmic matter of the nonvolatile kind, approximately. It includes everything, I suppose, except the inert gases, hydrogen, most of the water expected, carbon lost as methane, nitrogen lost as a volatile substance, and so forth. But the presence of the rest of the elements can be expected. Mercury is a comparatively volatile element, but the planets apparently accumulated at such a temperature and under such conditions that it was retained on earth; and now it is reported, I think rather reliably, in the meteorites.

But now this interior composition of the moon is to be investigated by seismic waves and the model (that I have presented in the *Astrophysical Journal* and in a couple of publications since) will lead us to expect that the iron masses inside the moon are distributed throughout in bodies the size of the iron meteorites or, occasionally, perhaps somewhat larger. I do not think that there is a core in the moon, but this is a matter of seismology.

and it will be interesting to see if we find a core or iron masses scattered around through the body of the material.

But we are going to talk this morning about what we expect to find on the surface of the moon. Let us ask some questions and see what sort of answers we can get. Is there nickel iron on the surface of the moon? I think there is. The surface has been bombarded by meteorites just as the earth has, and the metallic iron nickel contained in these objects has been scattered over the surface of the moon and has remained there. The only question is, how much iron nickel is there? A large collision occurred on the surface of the moon, first pointed out by Gilbert in 1893. There is evidence, as I will show you in some pictures in a moment, that rather large iron nickel objects traveled some 1500 kilometers across the surface of the moon, and plowed grooves in its surface. In that region at least, we may expect to find iron nickel. And if iron nickel was present in the objects that created Mare Imbrium, it probably was present in other material falling on the moon, even in very ancient times; so I expect that we shall discover substantial amounts of it on the surface.

Different Ideas

These expectations would be affected by different ideas as to the past history of the moon. Thus, I doubt all suggestions in regard to general melting of the moon at any time during its past history. If it was melted, we can expect the iron nickel to have sunk to the deep interior. And if pools of melted silicates occurred on the surface of the moon, the iron nickel of that material is at the bottom of the pool and not on the surface at all. We have to ask, therefore, what the physical history has been. One asks if there is basalt and granite on the moon. Basalt and granite are apparently produced by a partial melting of the earth and the flow of these materials from the interior. This apparently has been going on through geologic time, and we estimate that the amount of these materials arriving per year at the surface of the earth at the present time is about one cubic kilometer. If one multiplies this amount by 4.5 eons of time (4.5×10^9 years) it just about equals the entire crust of the earth. This seems to be the origin of granite and basalt on the earth.

Then, we immediately ask, was the moon made in a completely melted condition? Does the moon have a crust such as the earth has? Does the moon show evidence of volcanic activity at the present time, in the recent past, or since it was formed? Was the surface melted in any way so as to produce these materials?

Now, another thing that we might ask is whether the present surface of the moon is oxidizing or reducing? The meteorites are highly reduced objects with little ferric iron. We are not at all certain that all the ferric iron detected is not the result of oxidation after their arrival on the surface of the earth. But there is a most curious group of meteorites, namely, the carbonaceous chondrites. These contain considerable amounts of carbonaceous material; they also contain appreciable amounts of water, 10 to 20 percent. If the proportion of water were any higher they would be mud instead of rather solid rock. Carbon dioxide is given off from these objects, and one of my students in Chicago maintains that they contain free sulfur and sulfate. There is, therefore, a most curious mixture of reducing material, namely, carbon; and of oxidized materials, namely, carbon dioxide, sulfur, and sulfate. We turn to the moon and wonder whether the surface is oxidized in some way to materials of this kind or whether it is reducing. A few years ago I was going over some of R. W. Wood's early observations on colors on the moon in which he found an area that seemed to have the color of sulfur. But who

can believe that sulfur exists on the moon? It seems impossible; sulfur on earth is the result of the atmosphere oxidizing sulphides to sulphur. But when we look at these carbonaceous chondrites, we realize that they have been oxidized in some way, and it may indeed be that there is a patch of sulfur on the moon, and perhaps other oxidized material. We might look for them.

History of the Moon Surface

Now, in order to get at my ideas of the answers to these questions, I wish to show a few slides and discuss briefly what I think may be the history of the surface of the moon. What I will have to say is to a large extent merely a repetition, or a slight extension, of what G. K. Gilbert said in 1893. One day, while doing some research for a book I was writing on the planets, I went to the library and found an immensely impressive paper by this man Gilbert. I had read a great deal about the moon and subjects of this kind and I realized at once that I was reading the paper of an extremely competent scientist. The years since Gilbert seem to me to have been very unproductive. He was followed by Pickering. I have gone over some of the writings of Pickering, and I agree with him on one point, namely, that there are no people on the moon. But there we part company. I especially disagree with his treatment of Gilbert's work, particularly one sentence dismissing it as idle speculation.

I believe that an enormous amount of nonsense has been published in the lunar literature by people who have very little exact scientific knowledge. Gilbert attempted to apply some mathematics to his problems. He gave an explanation for the fact that the craters are circular. He pointed out that if other objects were traveling with the earth-moon system, they would fall from the vertical, and if they fell from the vertical one must expect that the collision craters would be circular in shape. Since then, it has been pointed out that high explosives, regardless of the angle of approach, also produce circular craters, but I am only showing that Gilbert considered this question in 1893, and tried to give an exact explanation.

There were many similar things in this paper. For example, he maintained that the moon was formed cold; that it was never completely hot, that there are not now, and never have been, any volcanoes on the moon. He drew pictures of volcanoes as you would expect them to be if they were not distorted by erosion, with a little crater at the top of an enormous smooth cone. And he maintained that there are not craters of this kind on the moon. I agree with him. The central mountains of the craters do not have this character; they sometimes have a little crater on the top, but they are not of the smooth shape to be expected if there was no erosion to destroy the original formation of such a thing as the Paracutin crater.

Gilbert maintained that the craters on the moon are mostly collision craters. He showed diagrams of their shape as compared with craters on the earth, and he explained the central mountains as being due to the rebound material on the inside. He found that there was no mutual overlap to craters; one was on top of the other, and not partly one way or the other. He discovered the

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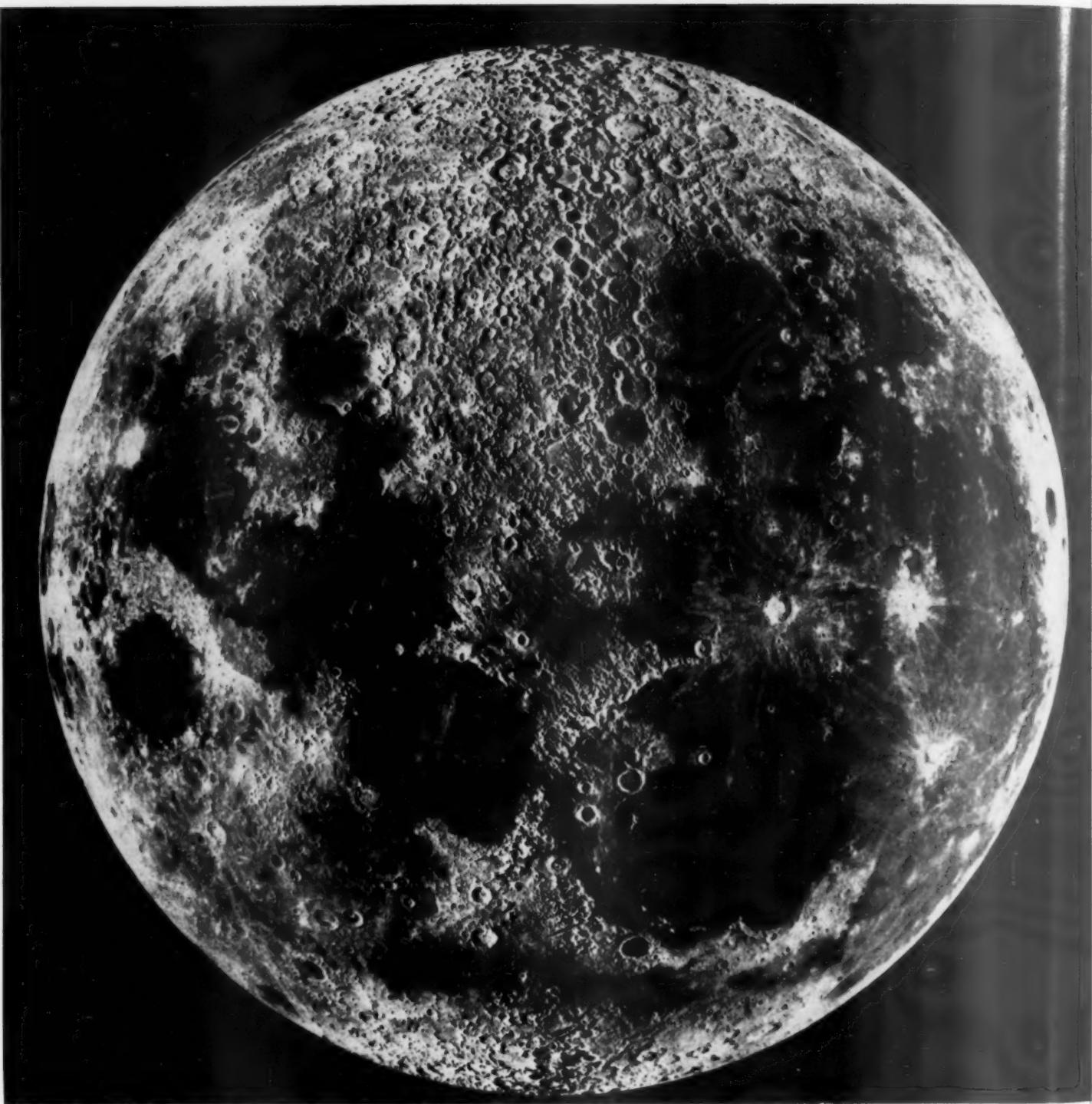


PLATE A

great collision in Mare Imbrium and described it in considerable detail. He also pointed out that there are craters on the moon that are not the result of collision. He explained that these often lie along cracks in the moon, and that one should not expect meteoritic objects to fall along a line on the moon's surface. However, these do not resemble terrestrial volcanos, but have broad mouths and very low rims. So, they were produced by some internal source of gas that blew material to the surface; or, perhaps, by the sinking of material in cracks in the moon; or by other things of this sort. What I wish to emphasize is that G. K. Gilbert was the first to recognize the existence of both types of crater.

I wish to discuss this big collision in Mare Imbrium in greater detail. This picture (Plate A) is a composite,

as you can see. The collision, according to Gilbert, occurred in the northern part of the mare. He mentions this area as being eccentric to the mare. It is outlined by a group of mountain peaks that form a circle just in front of Sinus Iridum, and you will notice the Alpine Valley running out to the left. You will see how prominent these mountainous masses, the Alps and Pyrenees, are here, and how they point away from the collision area. There are grooves in the center of the moon's disk that look as though they were plowed out by high velocity iron nickel masses. Coming to the east, we find mountainous masses in Mare Nubium all pointing from this collision area. As I say, this was first observed by Gilbert. He estimated the size of the object that fell here as 100 miles in diameter. I want to call to your attention the fact that the

ridges and grooves extend to the neighborhood of Ptolemaeus. They line the southern shores of Mare Serenitatis; some of them have skipped the mare into this region to the west.

Plate B shows another view of this collision mare, taken in such a way as to eliminate the foreshortening. As you will notice, the mare is quite circular, with certain irregularities. In the region before Sinus Iridum is an area without any large craters at all. This is what I called the collision area, and I think a careful reading of Gilbert's paper indicates that this was the area which he also spotted as the collision area. Then there is a shelf area between the collision area and the bordering mountains, in which you will see craters that are partially filled and partially covered. There are very jagged mountainous peaks sticking above the surface in this region just as though they had been tossed aside by some gigantic cataclysm and still remained above the flood of whatever this gray material is, usually thought to be melted lava, and so interpreted by Gilbert.

In this picture I have made an outline of the large circular area, the collision area, and Sinus Iridum, which is rather elongated. I suggest that the object that produced all this came in through Sinus Iridum at a low angle, plowed into the surface, broke up this area completely, and raised a bulge all around the area of the collision. Then, after the cataclysm was mostly over, the broken-up material sank down and left the very circular scarp. Of course, it is very difficult to prove exactly what happened, but there are great fault areas indicating a breaking along the general direction of the line between the mountains and the mare.

Subject Reviewed

This subject was reviewed by Ralph Baldwin in 1949 and I think he rediscovered this great collision, and then afterwards found that Gilbert had noted it previously. This collision provides much information in regard to the history of the moon. You will notice, first of all, that certain of the craters in this region are post-mare; for example, Aristophanes, Copernicus, Aristillus and Autolycus, are certainly post-mare, and there are others scattered around that must be also. But some are pre-mare; for instance, Julius Caesar, with a mass lying on top of it. Ptolemaeus is also pre-mare with many scars in its walls from the Imbrian missiles. It appears that one series of events shaped the moon. Some craters formed, then a very large object produced a mare, then more craters formed, and so forth, until finally the process ceased.

The whole surface of the moon, however, has been much influenced by this great collisional process. Every detail is affected in one way or another by the formation of either the smaller craters or the maria. We deduce that if the moon was near the earth, then the earth was receiving a similar bombardment and, as pointed out by Gilbert, the explanation for the battered appearance of the moon and the lack of destruction of the surface of the earth is that the process is very ancient. It was completed perhaps three billion years or more ago. We choose that figure because a very considerable portion of the earth's surface dates from that period, and it could not have been preserved in that form if the common bombardment of the earth and the moon had occurred later. This suggests to me that what we are seeing on the moon is ancient and that most of the features date back even to the origin of the solar system some 4.5 eons ago.

Now, this story is hardly the chemistry of the moon, but it does suggest some things that we must look for in a chemical study of the surface. In the first place, these great mountains fell on the moon; they were not the result of a folded structure; washed out by erosion, as

the mountains on the earth are. If a high-temperature origin is favored, one can assume that the moon, to begin with, was in isostatic equilibrium, and then, as a result of collision a great deal of additional material was placed on it. However, if the moon at that time was as plastic as the earth is now, these mountains would have sunk into the moon. (Large areas of this kind sink into the earth if ice is piled on them; or the areas arise when the ice is removed.) This would indicate that the moon, at the time the collisions occurred, was more rigid than the earth is now, and that it has remained that way since. This indicated to Gilbert that the moon was formed very rigid, was cold from the beginning, and never became greatly heated. It was unfortunate for Gilbert's theory that radioactivity was to be discovered in the same year, as I recall, and the facts of radioactivity make it very difficult to understand how any object of this kind could remain cold.

Now the question comes up: did melting occur in this area of Mare Imbrium? As a result of reading what other people have said, I believe it did occur. However, there seem to be great irregularities in smooth areas of this kind. Saunders and Frank many years ago investigated relative elevations on the moon. I studied their reports over the years and one day a young man, Eugene DuFresne, walked into my office and told me that he had been making a statistical study of their data. As a result of this study, he concluded that the measurements of Saunders and Frank were sufficiently good to prove the existence of very great differences in elevation in such areas as this. Other areas have been investigated recently by Watts in Washington. He maintains that the difference in altitude between some of the depressions and high mountains on the eastern limb is as much as 10 kilometers. Any such irregularities as that on the earth that were not isostatically compensated by a low-density crust would disappear in the course of a few million years. One can conclude again that the moon is cold at the present time, and highly rigid.

On this same plate are grooves that also point directly at this collision area. They have been explained as being due to iron nickel masses plowing through the moon, as mentioned above, and I am quite sure that the object that collided here contained considerable amounts of iron nickel. If this area was melted at the time, then that iron nickel has sunk to the bottom. But if this material is a fine dust produced possibly by collisional processes, we may suppose that it is a mixture of silicates and metallic iron. In fact, it might be of exactly the same composition as the chondritic meteorites.

Hence, when our space men arrive at the moon, I would like them to make a test somewhere in this region for iron nickel. A magnetic test of some kind would be quite satisfactory for this purpose. It would tell us what this smooth gray material is. Is it in fact dust, or gravel, or finely-divided, sand-like material, or was it completely melted? If it was completely melted, we may find that the time of melting was so short, and its solidification so rapid, that very little fractionation of the silicate crystals could occur, and the material may have a composition corresponding rather closely to the chondritic meteorites. Or it may be that the surface has a more basaltic composition than the material at depth.

There are other collision maria, and if we refer back to plate A, we will see them. If we eliminate the foreshortening, Mare Serenitatis is circular also; Crisium is circular, if you cut off this little western bay; as are Humorum and Nectaris. Fecunditatis might have been circular, but it is a very old mare with much material distributed on its surface. Mare Tranquillitatis does not look circular at all, but is a very irregular black spot.

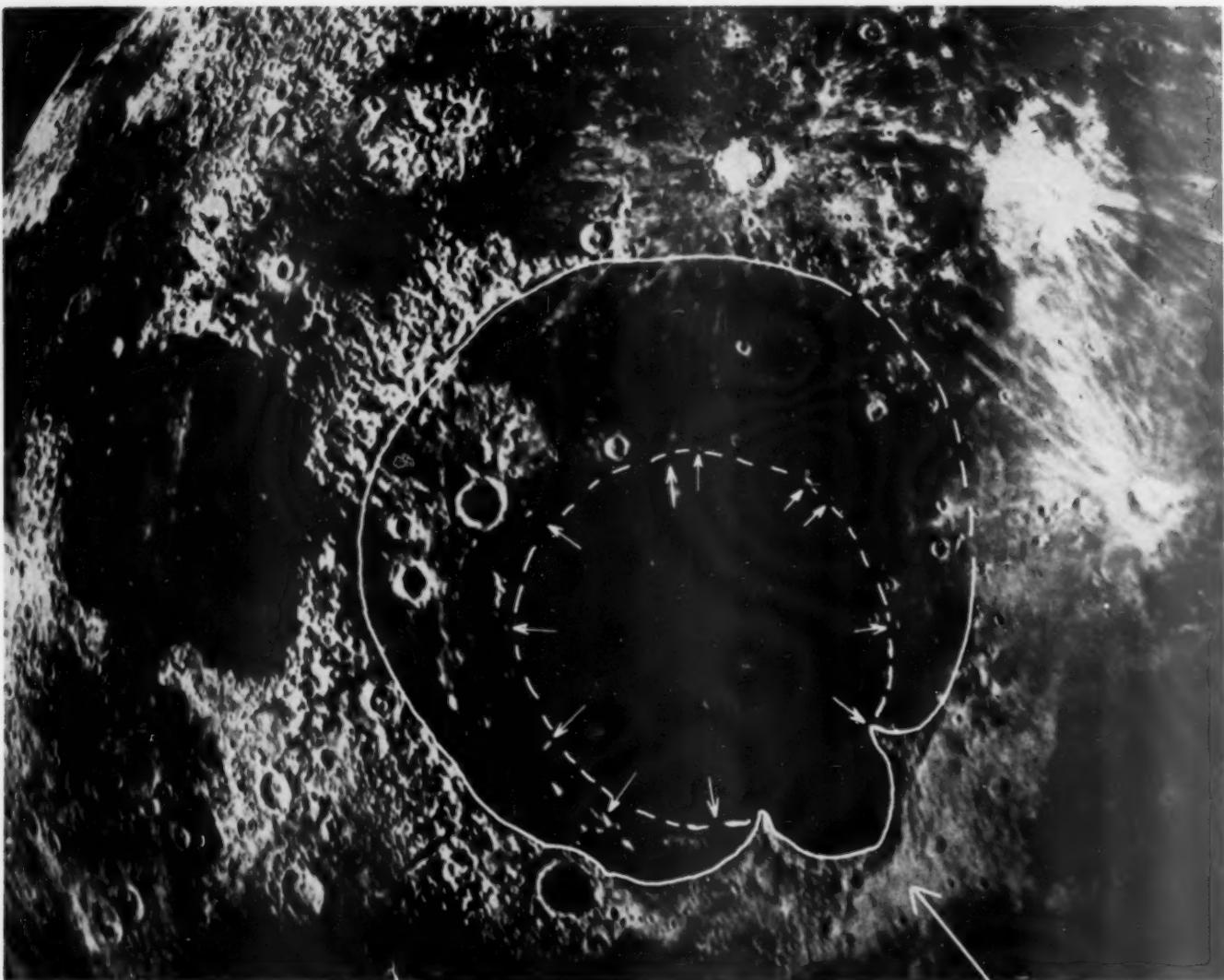


PLATE B

This looks to me like a lava flow, as though liquid lava some time flooded over this region and went back into all the bays and filled them up in some way. Distributed over this surface you will find craters, or bits of craters, that are distorted to some extent; and some appear triangular, as though the heavy lava had distorted the walls as it flowed around them. Some of them are post-mare.

Black Lava

There is another very curious thing about this region. One wonders which was made first, Mare Imbrium or Mare Serenitatis. Now, if Serenitatis came second, I would expect that it would have destroyed all of the fine structures between the two maria, which evidently are oriented with respect to the Imbrium pattern, and would have distorted the southern edge of the mare, and perhaps spoiled the Haemus Mountains. Hence, it seems to me that Serenitatis was formed first and Imbrium second. And then one wonders why great mountainous masses did not fall into this area and leave mountains on the surface. The explanation for it, which I gave some years ago, is that Mare Serenitatis was still molten and the great masses from the Imbrium collision just melted into the surface. One can say that the lava produced by the fall of this object in Mare Serenitatis flowed out into this area of Mare Tranquillitatis (it was a very black lava) and then the grey material from the Imbrium collision fell on top and spread out to the black line in western Mare Serenitatis, colored the surface grey,

and left part of the original black lava showing to the west.

On the other hand, if indeed this is not melted lava, but is finely-divided rock material, then it may be that these large masses, which would produce mountainous ridges, sank into the dust and left it covered with a dusty layer. This is more acceptable in some ways than the first hypothesis, because it is difficult to understand how the lava could remain liquid so long that the fall of a second object would be probable. But then, if I assume that this is solid, dusty material, how did the lavas flow over this area? I have no consistent solution to the problem. I hope very much that when we travel to the surface of the moon we will visit this area and discover what this black surface material of Mare Tranquillitatis is.

In the southeastern region of the moon there is a crater, Wargentin, that is brimful of some smooth material. Photographs do not show it clearly, but it can easily be seen through a telescope. It has been noted for a long time, and Gilbert suggested that the great collision that produced Mare Humorum produced melted lava which sprayed out all over the region and fell into Wargentin. He also suggested that the grey material in this area was due to the melted material that was thrown out and fell over the region; in fact, he says the whole appearance of this area suggests that it was covered with mud. If, on the other hand, these collisions produced dusty material, then it may be that the dusty

material filled Wargentin and gave us the smooth surface. An alternative suggestion frequently put forward is that lava flowed from the interior of the moon, rose to the surface, and overflowed. If this is the case, I think it must have occurred very early in the history of the moon, for otherwise we would have no way of accounting for the support of the enormously high mountains on the moon's surface. If lava can be produced in large quantities to fill up a crater like this, one can hardly expect the moon to have a hard, solid rigid structure capable of supporting these great irregularities. I doubt the lava hypothesis, but again it would be very interesting if we could land an exploration party right on Wargentin to learn at first hand what are the facts in this case.

Mare Nubium and Oceanus Procellarum look like lava flows again. You will notice that the lava, or whatever it is, has flowed out into all the little bays and valleys, partially submerging some of the craters. This ghost ring near Flamsteed, when viewed with foreshortening eliminated, is circular. If this was liquid lava and it flowed around the crater and flooded it, this occurred in such a way as not to distort the walls. A more likely explanation is that dust somehow settled into this whole area and covered it up.

Theories of Dust

I have used the word dust quite often, and I should mention that a couple of years ago Dr. Gold proposed a theory for the grey material on the moon. Certain things he said impressed me favorably. He pointed out that in the whole region up through the southern mountains, there is smooth grey material between the craters, on the inside of the craters, and everywhere. He said it seemed most unreasonable to him that molten lava would ooze up all over this area, between all the little craters and leave smooth grey material lying all over this region. When he pointed this out to me, I could only agree that I also thought the melted lava hypothesis was most improbable; but then he went on to say that the grey material is dust produced by light erosion of the cliffs and that the small particles of silicate traveled by a Brownian movement over the surface of the moon, and filled up all the maria and craters. I find many objections to this suggestion. It gives no explanation for the differences in color that we see, or for the variations in level within the great maria, or for the cracks that appear on all parts of the moon's surface. I do not accept Dr. Gold's theory for the origin of the dust.

But, at the same time, if one thinks of the great collisions that have occurred on the surface of the moon and realizes that they might have produced great clouds of dust rising in a temporary atmosphere and falling in various places, it is evident that this might well account for these great grey areas. Falling dust would leave the craters relatively undistorted.

The heat balance of the moon and the distribution of temperature with time and radius can be calculated on various assumptions, e.g. (1) a completely melted moon initially with all the radio-active elements concentrated at the surface, (2) a completely melted moon with part of these elements distributed throughout the moon, (3) an initially cold moon with all of these elements distributed uniformly throughout, and other more complicated models. It is difficult to keep the interior rigid on the basis of the first two assumptions because of the very gradual loss of heat from a body as large as the moon. The third assumption may be consistent with great rigidity on the moon's interior. The moon has an irregular shape, with a bulge toward the earth about one kilometer high, whereas the equilibrium height would be about 60 meters. I do not believe that bulge could be

supported if the interior of the moon were melted, or, indeed, if it were really close to the melting point.

This problem in regard to the thermal history of the moon is an important one, and I do not think I have solved it satisfactorily; but it is very difficult to account for a completely rigid moon unless we have somewhat greater conductivity of heat from the inside than is generally accepted. Recently, it has been found that light radiation is an important conductor of heat around 2000 degrees and above, and it may be that that solves the problem of keeping the moon rigid at the present time. This might be true on a variety of assumptions.

Summarize

Now, I wish to summarize my conclusions. In the first place, I would like to say that I doubt very much that the moon has a crust similar to that of the earth. I believe the crust of the earth is due to partial melting of the interior during its long history, and that it is about 15 kilometers thick on the average. It could be due to melting, producing basalts at approximately the rate observed at the present time. I do not believe that this is the case on the moon. If it were so, the moon would have a regular, equilibrium shape, at least up to the present time. One must remember that the earth is a large body; the ratio of its loss of heat through the surface to its generation of heat is small as compared to the moon. One cannot expect that the moon will be as hot or as active with respect to melting processes as the



PLATE C

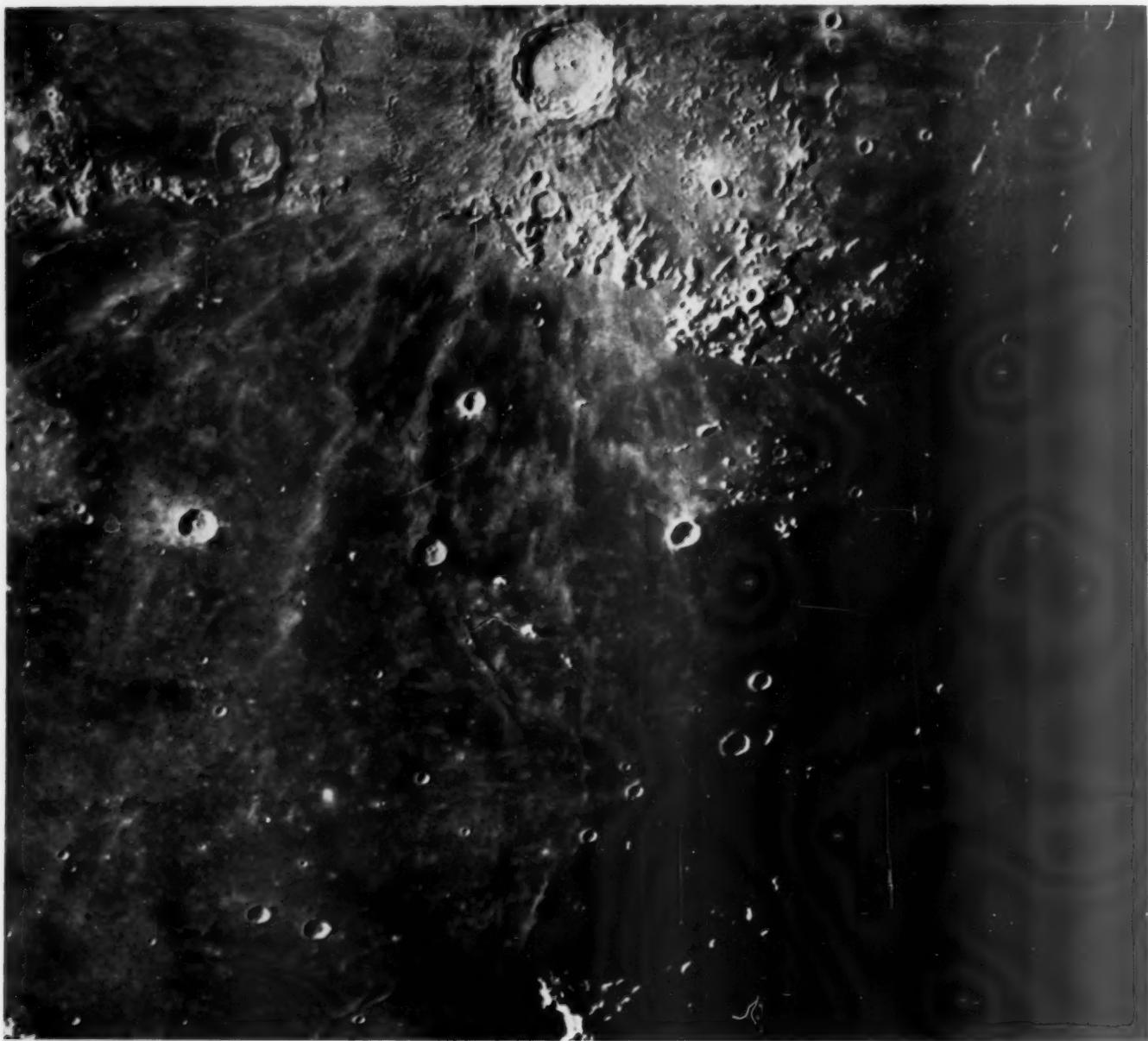


PLATE D

earth. If basalts and granite are present, they should be very local phenomena.

I have not referred to the white areas of the mountainous regions of the moon. I do not know what makes them so white. I think the black areas might be due to an admixture of graphite; we do find carbonaceous chondrites with a considerable amount of black material in them. I rather suspect that there are no important large deposits of granite and basalt, but this does not rule out the possibility of the presence of small amounts. Materials of the kind of the achondritic meteorites must have been produced somewhere, and they were produced, according to my ideas, in primary objects; and I have assumed that the moon is such a primary object. Hence, I must believe that granite material and basaltic material are present. I would like to point out that we should expect to observe, to a certain extent, chondritic meteoritic material on the moon. And, if the circular maria are the results of the breakup of great quantities of this primordial material, all of this material may be something of the composition of the chondritic meteorites. This should certainly be looked for.

Oxidized material should be sought because, if a temporary water atmosphere were subjected to the light of

the sun, it would be possible to produce oxidizing conditions temporarily. And the oxidizing conditions might well produce carbon dioxide, sulfur, sulfate, and some ferric iron on the surface. There are black spots on the moon, and Plate C shows some of them. Near the center of the moon's disk you see these enormously black ridges; they have an orientation indicating that they came from the collision in Mare Imbrium. They are so black that unless one gets them close to the terminator, one cannot see them at all. These might be due to a mixture of carbonaceous material and, in fact, the carbonaceous material might account for the difference in the grey color of the maria and the other parts of the moon. Carbonaceous material should certainly be looked for.

Now, I wish to call attention to another phenomenon on the moon. On plate C, you see wrinkles on the surface. They seem to follow the shore lines in some cases. There is a wrinkle going down across Mare Imbrium, and it just might be a continuation of the crack to the south. You will find these wrinkles all over the surface of the maria, whether they are of the flooded type (Mare Nubium, Oceanus Porcellarum, and the connecting sinuses) or whether they are the deep collision maria.

Plate D shows Mare Imbrium again, and you will notice a great wrinkle running down the right-hand side of the mare. This is at approximately the edge of the collision area. The mountainous masses outline the collision area, but the wrinkles go straight across them.

In the other parts of Mare Imbrium, the wrinkles go right through and deep collision area and the shelf area. They are present in the shallower maria, everywhere on the surface of the moon. They are in Mare Tranquillitatis, a very black mare; they are in Mare Serenitatis which joins it. They look very much the same in all of them. What they are remains quite a mystery. People have said that they are frozen waves of lava. I do not know how waves of lava would freeze into such a shape as this. They are some 100 meters high or something of that sort, ten to twenty kilometers broad, and hundreds of kilometers long, as you see.

A suggestion has come from Professor Kuiper that they are the termini of lava flows, and he called particular attention to those in western Mare Imbrium. In this region we have little wrinkles, and he thought there was an eruption of lava along the region between Maria Imbrium and Serenitatis and that it flowed down-hill to make these wrinkle-like ridges which seem to be high on one side and very gradual on the other. But what makes all the others? Do we have other lava flows all over the moon with no apparent sources for the lava? This presupposes lava flows all over the surface of the moon. I do not believe that is a valid explanation. If a lava flow existed to produce a terminal ridge, I would expect that the source of the lava would also be visible, but it is not.

In August, I traveled by air to Central Asia. We were flying at 10,000 to 11,000 kilometers, and I looked down at the sand dunes of the Caspian Sea. Those dunes had

many small ridges and some very large ones, and I could not help wondering if these ridges on the moon might not be sand dunes. But if they are sand dunes, the moon must have had an atmosphere, at least for a while. This, I think, is not an impossible assumption, because degassing of the great objects that fell on the maria should have occurred, and temporary winds may have piled them up. Although this puzzle is not quite chemical in character, I wish one of our space ships would land close to one of these wrinkles and tell us what they are.

AUSA TO BUILD ARMY MEMORIAL

To establish an Army Memorial Museum in Independence Square, Philadelphia, the Association of the United States Army is seeking contributions which will commemorate the U.S. Army at its birthplace.

A sweeping renaissance has been underway with restorations of early Philadelphia around Independence Hall, where this memorial to the Army of the Revolution is planned.

Lieut. Gen. Milton G. Baker, president of AUSA, has found the plan supported with well-wishes of members of the present Army Command.

Contributions may be sent the Treasurer, AUSA, 1529 18th Street, N.W., Washington 6, D.C.

MISSILE BASES

(Continued from page 16)

fiscal budget contains requests for a quarter-billion dollars, and it is expected that additional funds will be required in future years.

Fast Reaction

Acting on the heels of the Congressional recommendations, the Secretary of Defense reorganized the various phases of the ballistic missile effort into the Ballistic Systems Division of the Air Force Systems Command. It is one of the four divisions of the Air Force Systems Command.

Getting away from the bases and to the missiles, the prime contractor for Atlas is Convair, building the airframe, and other contractors are General Electric and Burroughs for guidance systems in radio; while ARMA has the inertial guidance, Rocketdyne the propulsion, and General Electric the re-entry vehicle.

The Martin Company is prime contractor on the Titan. Other contractors include: Bell Telephone and Remington-Rand for guidance, AC Spark Plug for inertial guidance; propulsion is with Aerojet, re-entry vehicle is the work of Avco Corp., launcher system by American Machine & Foundry, propellant loading system by A. D. Little.

Boeing Aircraft is the prime contractor for the Minuteman.

HERE ARE SOME CHANGE ORDERS CITED BY THE SUBCOMMITTEE TO SHOW THE VARIANCE OF COSTS AND ESTIMATES

Change	Preliminary architect-engineer estimate	Preliminary Corps of Engineers estimate	Contractors proposal	Final Settlement
Forbes, modification No. 12	\$ 60,000	\$200,000	\$1,782,312	\$1,203,335
Lowry I, modification No. 1	51,011	500,000	7,803,263	4,937,373
Lowry I, modification No. 29	60,000	60,000	1,059,405	1,059,405
Offutt, modification No. 10	none	300,000	1,432,593	750,000
Schilling, modification No. 84	none	235,000	1,572,665	(1)
Walker, modification No. 11	333,960	335,400	3,489,787	(1)
Warren III, modification No. 9	81,000	127,123	492,079	233,968
Lowry II, modification No. 2	252,000	252,000	2,605,687	(1)
Forbes, modification No. 94	none	375,000	2,245,358	(1)
Beale, modification No. 2	-11,314	69,298	145,954	87,700

ORIGIN OF LIFE ON EARTH AND ELSEWHERE

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WHENCE CAME LIFE on the surface of the earth? Whether or not a complete answer to this question may be found within the context, and content, of modern science, may be a moot question. It is our purpose to see how far we can devise an answer, and how satisfactory it may be, within that context. It becomes clear immediately that we will be dealing, not only with the advances of biology that have occurred, but with all of the contiguous sciences—physics, chemistry, geology, astronomy, and the like. However, our primary point of view will be that of biology and chemistry.

In trying to provide this answer we will have to review the practical, concrete knowledge in these areas, as well as the impact they have, and will have, on man's view of himself and his place in the universe. At every point of our discussion we will limit ourselves to asking questions and providing answers which, at some point, may be susceptible to observational or experimental test.

We trace a path from the primitive molecules of the primeval earth's atmosphere condensed from space; through the random formation of more or less complex organic molecules, using the available energy sources of ultraviolet light, ionizing radiation or atmospheric electrical discharge; through the selective formation of complex organic molecules via autocatalysis; finally, to the information-transmitting molecule which is capable of self-reproduction and variation. In addition, somewhere, either during the course of this "chemical evolution," or perhaps succeeding it, a system has been evolved in which the concentration of the reaction materials was retained in a relatively small volume of space, leading to the formation of cellular structures. Man is about to send some bits of dust back into the space from which it originally came. It is thus not only timely, but more significant than ever before, to ask again the question: What are the probabilities that cellular life as we know it may exist at other sites in the universe than the surface of the earth?

We can assert with some degree of scientific confidence that cellular life as we know it on the surface of the earth does exist in some millions of other sites in the universe. We thus remove life from the limited place it occupied, as a rather special and unique event on one of the minor planets, to a state of matter widely distributed throughout the universe.

Since we have used the phrase, "the origin of life," we presumably have a clear conception of what we mean by the term "life." On the ordinary level of human experience, there is no difficulty in distinguishing that which lives from that which does not. However, when we explore this notion to try to determine precisely what it is, or—to be even more specific—what qualities we must devise in order to produce something which lives from something which does not, with no help from a living agency save the hand of man, the term becomes somewhat ambiguous. For example, there are many qualities which we have no difficulty in attributing to a living organism. It is able to reproduce itself, to respond to an environmental change (come in out of the rain), to transform energy into order (sunshine into leaf, leaf into hair); to change and remember the change, and so

forth. While many of these individual characteristics may be duplicated in systems in space, one or more at a time, it is only when a sufficiently large collection of them appears in a single system that we call that system alive.

Thus, the definition of "life" takes on the arbitrariness of the definition of any particular point on a varying continuum, and precisely where that point will fall on the line of time and evolution will depend upon who is watching the unfolding of that line.

With this last remark, we have introduced the basic notion of evolution which, since its precise formulation exactly one hundred years ago by Darwin and Wallace, has pervaded all of science. In fact, most of what I have to say could be formulated in terms of a long extrapolation, backward in time, of the notions that were expressed by Darwin and Wallace in 1958, but which they did not extend very far back, either in geologic time, or certainly in cosmic time.⁽¹⁾

As most of you know, for a period of over sixty years any serious discussion of the question of the origin of life was not indulged in by scientists, particularly by experimental scientists. In fact, it was considered a disreputable kind of activity. It is interesting to examine what some of the reasons for this might have been. Certainly one (and perhaps a dominant one) was the dictum of a contemporary of Darwin (1809-1882), a chemist, Louis Pasteur (1822-1895), who in 1864 quite clearly provided an answer to the question which, for many decades, had been the subject of much discussion—the possibility of the spontaneous generation of life on earth today. Pasteur quite clearly and definitely established, in his experiments of 1864, that it was impossible on the earth today, under controlled conditions, to demonstrate the appearance of living material except through the agency, or as the offspring, of other living material. While Pasteur opposed the Darwinian formulation of evolution, largely on religious grounds, I suspect that he either knew consciously, or felt instinctively, that the Darwinian doctrine was conceptually in conflict with his experimental conclusion.⁽²⁾ A search of the works of Darwin has revealed no mention of his opinion of the conclusions that Pasteur reached in 1864.

In any case, for over sixty years thereafter, as I mentioned earlier, there appeared practically no serious discussion about the spontaneous generation of life. Between the publication in 1870 by Alexander Winchell, a professor of geology, zoology and botany at the University of Michigan, of a book entitled "Sketches of Creation"⁽³⁾ and the statement by J. B. S. Haldane, professor of biology, in 1928,⁽⁴⁾ there appears to be no serious attempt to answer the question of the origin of life within the context of the science of the period.

The hiatus came to an end with the recognition by Professor Haldane that the dictum of Pasteur was not in conflict with the backward extrapolation of the doctrine of evolution as expounded by Darwin and Wallace, if one recognized that at the time that spontaneous generation must have occurred there was not, by definition, any living thing on the surface of the earth. Therefore, it was possible, in the prebiotic time, to accumulate large amounts of organic material generated by nonbiological

processes. This, of course, cannot take place on the surface of the earth today, since there exist everywhere on the earth's surface both microorganisms and macro-organisms which would transform any such organic material immediately it is formed, even in small amounts. Thus the apparent conflict of concept between the backward extrapolation of evolution and the dictum of "no life save from life" can be, and has been, resolved.⁽⁵⁾ Since that time (1928), it has become increasingly popular amongst scientists (experimental and otherwise) to examine the question of the origin of life from the scientific point of view. In fact, it has become so popular that within the last 18 months there have been held at least two conferences in the United States, and one international conference, on the subject.

It seems wise to have a look at the time we have in which to accomplish this total evolution of life. Figure 1 shows the order of magnitude of that time in relation to the geologic history of the earth. The earth was formed from matter in space some four to seven billion years ago. Whether this was an aggregation of cosmic dust or the result of a primeval explosion remains a matter of controversy, and will come up again a bit later in this discussion. However, that terrestrial history itself is only some five billion years in extent seems to be well established. You can see in Figure 1 that the evolutionary periods on the surface of the earth have been marked to correspond with the known geologic eras.

The earliest period might be spoken of as the period of evolution of the present earth. Overlapping this, and including the Archeozoic and Proterozoic geologic eras (some four to two billion years ago) is the principal period of which we will speak, the period of chemical evolution. It was during this time that the formation of more complex organic molecules from simple ones occurred by nonbiological processes, which we will try to describe in a moment. Overlapping the period of chemical evolution we have marked the period of "organic evolution." This period is the one whose later part is recorded in the form of fossils. However, for its greatest part, beginning some time in the Archeozoic period and extending through the Proterozoic period, there is no fossil record. This period of organic evolution of the soft-bodied living organisms, which left no fossils, constitutes by far the longer fraction of the period which we call "organic," or "biological," evolution. Finally, at the very apex of the entire structure exists a point which we call the "evolution of man." This constitutes only a minute fraction of geologic time—something like the last million years.

It should be noted that one of the prerequisites of all of the speculation about the origin of life is that there exists a means of gradually producing relatively complex organic substances by nonbiological processes. This question is susceptible to experimental investigation, and has been investigated by a number of experimental scientists, with positive results. It is clear that in order to test any chemical process as a possible means of generating organic material by nonbiological means, we must first know what the raw materials for these chemical processes must be. This, of course, entails some knowledge of the nature of the atmosphere of the primeval earth. This, in turn, requires a concept of the mode of formation of the earth and the solar system in which it exists. There have been a wide variety of hypotheses on this point. For example, Shapley in his recent discussion, lists some fifteen different hypotheses with regard to the origin of the earth and the solar system.^(6a,b) One thing is common to all of the hypotheses: that the earth did have a solid crust and some kind of gaseous atmosphere. The question that is open to some discussion is whether that crust and

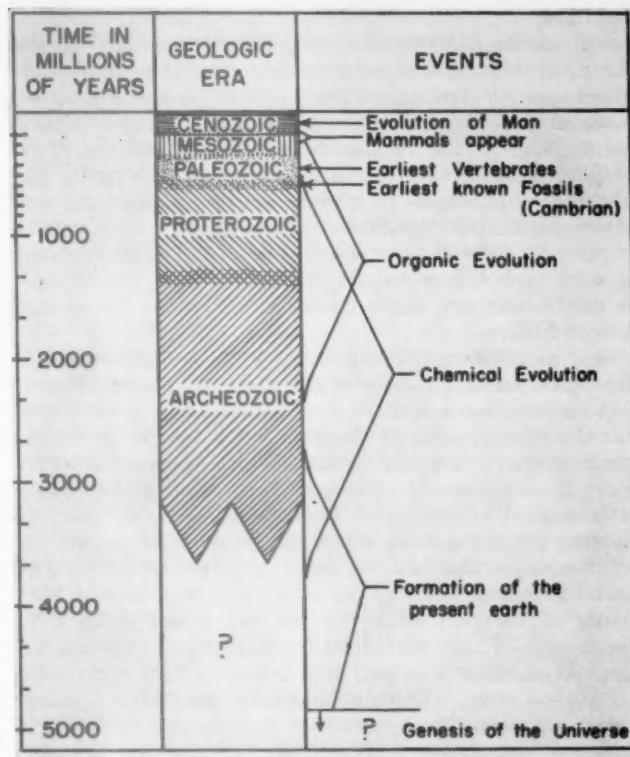


Figure 1. Time scale for total evolution

atmosphere were primarily oxidizing or primarily reducing in character. In the former case, the dominant partners for all the atoms are oxygen atoms, while in the latter they are hydrogen atoms.

It is clear that no matter what concept one accepts for the origin of the earth, the atmosphere itself must have been made up of relatively simple molecules such as nitrogen, ammonia, possibly carbon dioxide, methane, hydrogen, and the like. A group of these molecules is shown in the first row of Figure 2. There has been considerable discussion as to whether the oxidized molecules or the reduced molecules constituted the major portion of this atmosphere. It would appear that the present consensus favors the reduced group. In any case, experiments have been done with both types of atmosphere.

The agents which have been called upon to produce the initial transformations have nearly all been of the high-energy type—ultraviolet radiation, electrical discharge radiation from the radioactivity of earth-bound minerals, or radiation coming to us from outer space in the form of cosmic rays.⁽⁵⁾ Since it appears that all the concepts of the earth's formation involve the absence of molecular oxygen from its primeval atmosphere, the intensity of ultraviolet light which impinged on the surface of the earth in its early days was considerably greater than it is today. So, some of the earliest experiments designed to determine whether it was possible to form more complex organic molecules, containing carbon-carbon bonds, were done using ultraviolet light as the source of energy. They were described by Haldane as early as 1928, and they have been checked since in many laboratories throughout the world. The primitive carbon compounds used in most of these experiments were already partly reduced (carbon monoxide, formic acid, or formaldehyde).⁽⁴⁾

Again in 1951, experiments were instituted in our laboratory to determine the usefulness of high-energy radiations, such as those which might be derived from the natural radioactive materials that were present in

relatively high concentrations in the primitive earth, or from cosmic radiations coming in from space.⁽⁷⁾ Here, the primitive carbon compounds were of the more oxidized type—strictly speaking, carbon dioxide. However, molecular hydrogen was also present in these experiments. The partial reduction of carbon from the completely oxidized form of carbon dioxide to a partly reduced form, such as formic acid or formaldehyde, was observed. In addition, new carbon-carbon bonds were apparently formed upon irradiation of aqueous solutions of such carbon compounds, leading to compounds such as oxalic acid and acetic acid, as shown in the second row of Figure 2.

Still more recently, beginning with the premise that the primeval atmosphere was of a reducing character, experiments were undertaken which were designed to test the effectiveness of electrical discharge in the upper atmosphere (a reduced atmosphere) to create materials more closely resembling those which are presently used in biological activities.⁽⁸⁾ Here the compounds used as starting materials were water vapor, methane, ammonia and hydrogen. As you see, these were primarily the reduced forms of each of the elements—that is, the elements of oxygen, nitrogen, carbon, attached only to hydrogen. When an electric discharge was passed through such a mixture, one indeed did get a large variety of more complex materials, particularly those known as amino acids, of which the simplest, glycine, is shown in the figure. It is perhaps worthwhile to point out that having first reduced the one-carbon compound in the high-energy experiment and then formed a two-carbon compound by connecting two carbon atoms in the form of acetic acid, it was possible to demonstrate the generation of succinic acid, a four-carbon compound resulting from the combination of two molecules of acetic acid, by irradiation with high-energy radiations such as those which one might obtain from radioactive materials. It is interesting to note that these latter experiments, as well as the first ones of 1951, were performed using a cyclotron rather than natural sources of radio-activity because of the high intensities of ionizing radiation which could be obtained.

One suggestion of a very different type was among the early ones used, since the elementary chemistry was already well known. This chemistry begins with metallic carbides,⁽⁵⁾ which, on contact with water, will provide a variety of hydrocarbons such as methane and acetylene (the latter the familiar process used in the older miner's lamp). Some of these gases are of such a character that if they come into contact at high enough concentration with any of a variety of mineral surfaces, they will com-

bine with each other to produce large, complex molecules, sometimes with very specific configurations.⁽⁹⁾ The metal carbides used to start such a process generally require high temperatures for their formation, and it will therefore be necessary to suppose either that the earth began very hot, or that it has had places in it, or on it, that were hot enough to form such carbides and later deliver them to the cooler surfaces. There appears to be no geologic evidence for the primary existence of such carbides in the deep rocks.

Very nearly all of these processes which we have just described for the generation of new carbon-carbon and carbon-nitrogen bonds and the creation of more complex molecules from simpler ones depend upon the primary disruption of the simple molecule into an active fragment, followed by the random combination of those active fragments into something more complex. As the material present in the atmosphere and on the crust of the earth is gradually changed from the simple to the complex, these methods of transformation will not select between the simple and complex and are just as prone to destroy by bond breakage the products of their initial activity as they are to create new ones. It is from here that we must now call upon some method of selective construction of molecules.

To do this we need only to call upon the phenomenon of autocatalysis, well known to chemists.^(10a) This phenomenon occurs whenever the product of any chemical transformation has the property (catalytic) of influencing the rate of its own formation. It is surprising that this phenomenon was not utilized long ago in such discussions as these, since it is in essence the mechanism of all selective evolutionary processes.

Thus, it is apparent from Figure 3 that of three possible transformations which A might undergo, namely, to B, to C or to D, it will undergo more frequently the transformation to D because D itself is a better catalyst for that transformation than it is for the others. Therefore, eventually the random processes which gave rise to A will not be quite so completely random in their further effectiveness. They will, in this case, tend to produce D rather than B or C, from A. In general, the result of autocatalysis, and of higher evolution as well, is not all-or-none, as we have just described it, but degrees of each. Thus, it is likely that all three substances, B, C, and D, are catalysts for their own formation, but the most efficient will eventually supersede the others.

It is of interest to examine how this sort of chemical selectivity might have functioned in the development of an extremely important biological material—the porphyrins, which give the red color to blood cells and the green color to leaves. We have already seen how the simple precursors to porphyrins, succinic acid and glycine, might be formed (and, indeed, were formed) by a random process from the primeval carbon-containing molecules. Now we have available to us a method of tracing the route by which these two precursors eventually become porphyrins in present-day living material; some of the essential steps in that series are shown in Figure 4.⁽¹¹⁾

Underneath the center sequence are indicated, by arrows, a number of possible points where the catalytic function of iron might play a role. For example, iron may play a part in the combination of succinic acid and glycine to start with; or in the decarboxylation of the primarily-formed keto adipic acid which is the second compound in the center row; or finally, in one of the several steps which are necessary to convert the delta-aminolevulinic acid into the macrocyclic, or large-ring, compound known as protoporphyrin No. 9, at the right-hand side of the figure. We already know that a number

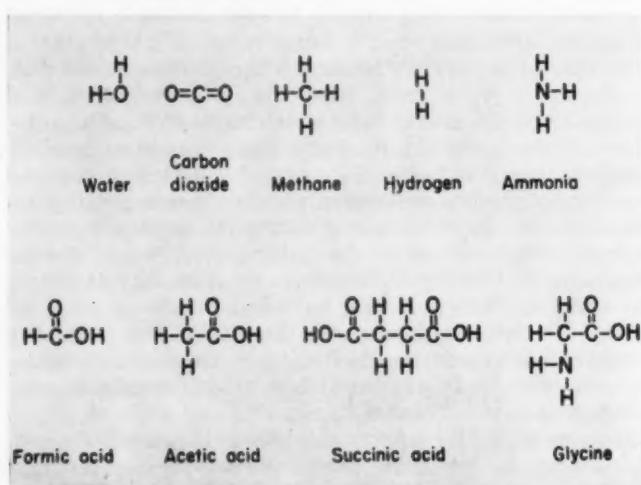
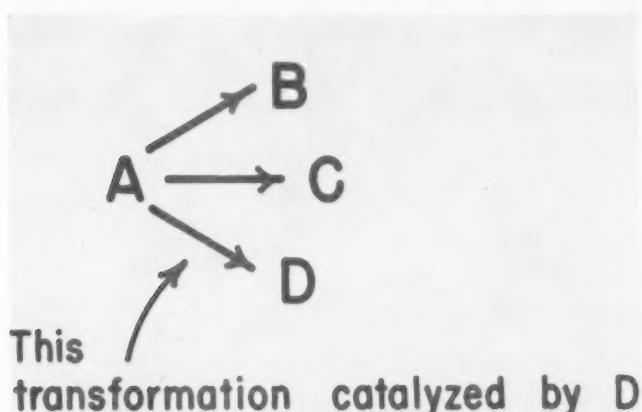


Figure 2. Primeval and primitive organic molecules

of these steps are definitely catalyzed by iron, but what is more important is that some of them are much more readily induced to go by the iron ion after it has been encased in the porphyrin No. 9, as shown by the dotted circle in the porphyrin, than they are by the bare iron ion. Such an iron porphyrin is a much better catalyst for several of the steps leading to its own formation than is the bare iron ion itself. Furthermore, it is almost certainly a better catalyst for the conversion of the levulinic acid toward the porphyrin than for the competitive conversion of the glycine back toward the carbon dioxide from which it came. Thus it is clear that the route from succinic acid and glycine to the porphyrin, once the porphyrin has been formed, will be greatly facilitated by



AUTOCATALYSIS

Figure 3.

the incorporation of iron into it, thus bringing a good deal more of the succinic acid and glycine into this particular, and important, form.

The process of the development of the catalytic function of iron does not, and has not, stopped at this point. When the iron compound is built into a protein (a macromolecule made by the combination of many amino acids), its catalytic efficiency may be increased still more. Beyond this, the variety of chemical changes in which it may assist can be increased and the efficiency of its function diversified.

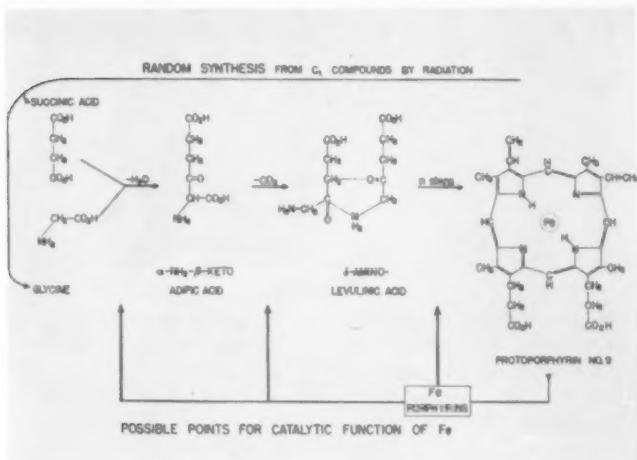


Figure 4. Biosynthesis of porphyrin and the evolution of the catalytic functions of the iron

Other atoms and groups of atoms having rudimentary catalytic powers can be developed into the highly efficient and specific catalysts which we know as enzymes in even the simplest of modern organisms, by exactly analogous processes of chemical selection by autocatalysis. And it is almost certainly no accident that these enzymes are all proteins. For it is only the proteins as a class that offer the combination of simplicity of formation (peptide bond) with practically an infinite variety of chemical functions (R groups).⁽¹²⁾ See Figure 5.

So far, all of the processes of which we have spoken have been described as taking place in a rather dilute solution, with the molecules randomly arranged. The development of a complex material under such circumstances could not go very far. Two further stages of change seem to be required: (1) the ordering of the molecules in some rather specific array, and (2) the concentration of the formed substances into relatively small packages. Which of these two processes took place first, or whether they were indeed successive or simultaneous developments, is hard to say. However, that both of them took place we do know, and that there exist mechanisms for each of these processes to take place we can also demonstrate in the laboratory.

For example, one type of molecule with which we are constantly dealing, both in the laboratory and as a result of present-day biological action, is the large, flat, "aromatic" molecule. The porphyrin that we have just mentioned constitutes one such, and there are many others. Such molecules, when they reach a certain minimal level of concentration in aqueous solution, will tend to drop out of that aqueous solution. However, they will not drop out in a random way. Because of their peculiar flat shape, they will tend to drop out in an arrangement in which the molecules are piled one on top of the other, much like a pack of cards. If one throws a pack of cards in the air and allows them to fall onto the floor, it is

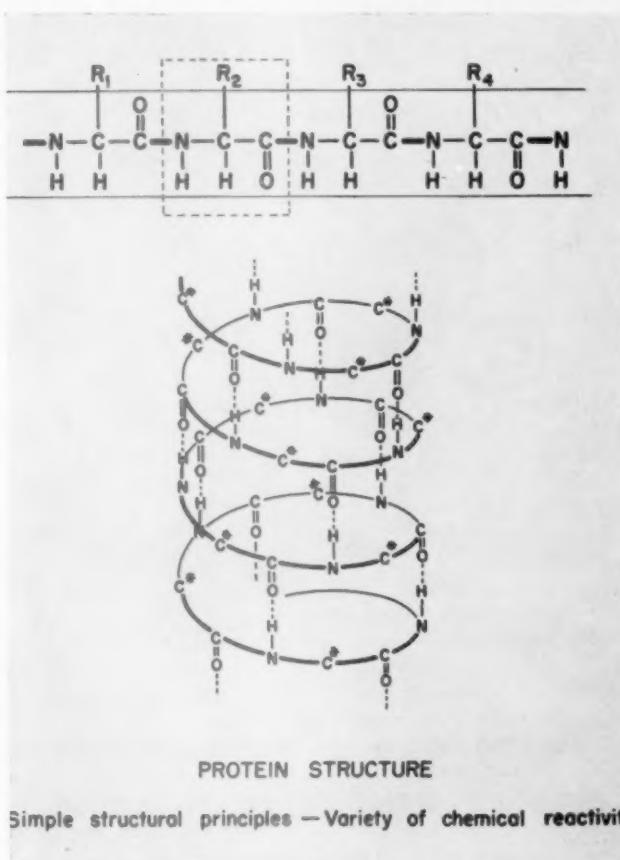


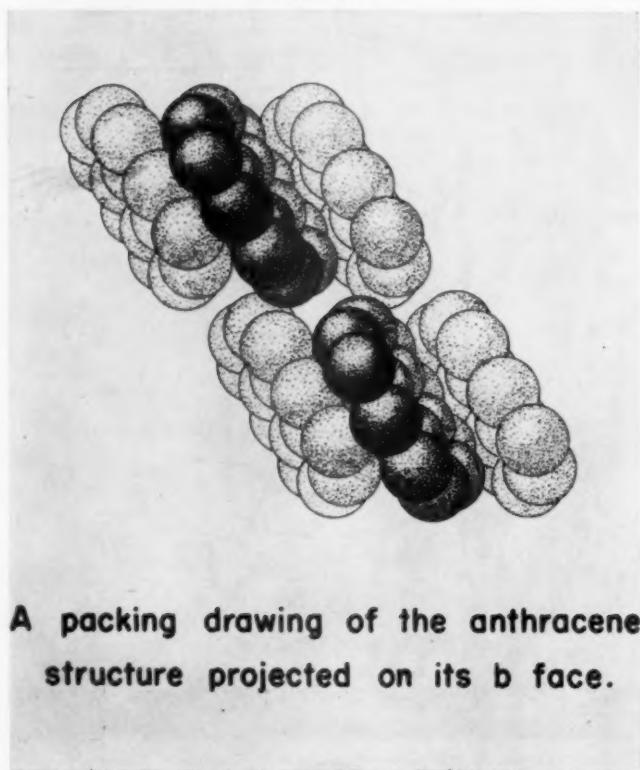
Figure 5.

unlikely that they will fall standing on edge. They will practically all (if not all) land flat, one on top of the other, because of their peculiar shape. This kind of phenomenon illustrates the way in which large, flat molecules tend to come out of solution in crystals. Figure 6 shows a diagrammatic drawing of a simple crystal of a rather simple flat molecule, and here you can see the result of the tendency of such molecules to pile up, one on top of the other.^(10b)

I use this particular example with a purpose in mind. The reason is that much of the information that present-day living organisms carry with them and can transmit to their offspring in the form of genetic material is made up, or seems to be contained, in an ordered array of such flat molecules as this. The additional feature that one must add to this piling-up of flat molecules is that they are not independent, as the cards were, but all tied together along an edge, as though the cards were attached to each other by a double string. The example of the flat units that we will use here will be the pairs of complementary bases as they are found in desoxyribonucleic acids (DNA), the material of which the chromosomes are constructed. Figure 7 shows these pairs as they occur: thymine paired with adenine and cytosine paired with guanine by virtue of their peculiar structure, which places certain of their hydrogen atoms between oxygen and/or nitrogen atoms on the complementary molecule. These four molecules, and one other very closely related to thymine, are themselves formed from the same primitive precursors described in Figure 2 (succinic acid, glycine, formic acid, carbon dioxide and ammonia). Along either edge of these flat units can be seen the sugar-phosphate chain which corresponds to the string in the pack-of-cards analogy.

Because of their peculiar aromatic type of structure, these base pairs will tend to line up one above the other. This tendency will, of course, be increased because they are not independent of each other but tied together by the sugar-phosphate ribbons. In actual fact, the structure of DNA seems to be such a flat piling up of the nucleoside

Figure 6.



bases, with the sugar-phosphate ribbons twisted in a spiral around the outside, as shown in Figure 8.

The other aspect which must obtain, and of which we spoke a moment ago, is the concentration of these organic materials into relatively small space, leading ultimately to the formation of cells as we now know them as the units of living matter. It is at this point that our information and our analogies are most diffuse. A number of physical-chemical processes have been called on to participate in the development of the living cell. First among these is the appearance of surface layers, or boundary layers, such as one sees in a soap bubble. Here we are quite familiar with mechanisms for producing a rela-

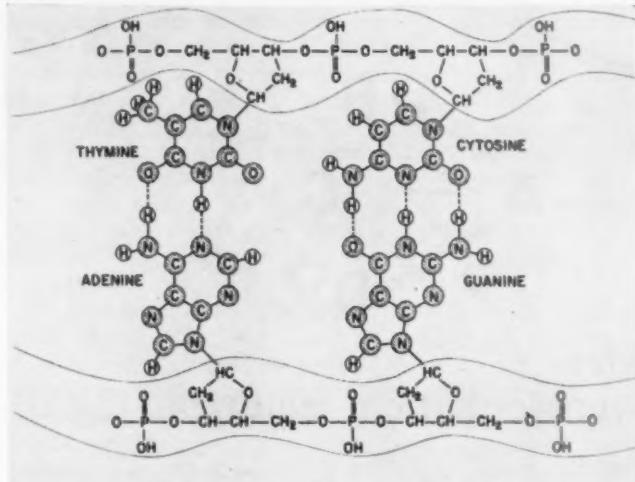


Figure 7. Molecular drawing of the components of desoxyribonucleic acid—genetic material

tively stable and well defined boundary layer between two phases. Another phenomenon much less familiar to us is known by the name of "coacervation" and has been called upon as a primary phenomenon leading to the development of local concentration and cellular structures.⁽⁵⁾ This phenomenon is dependent upon the ability of giant molecules in water solution to separate out from the dilute water solution into relatively more concentrated phases, or droplets, suspended in the more dilute water solution around them. Beyond this, the giant mole-

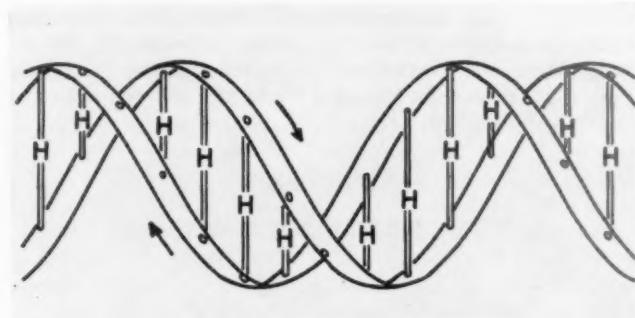


Figure 8. Double helix model for desoxyribonucleic acid

cules tend to pack themselves in ordered arrays, provided they, themselves, have ordered structures.

As an example of this relationship between an invisible structure and the visible structures it can produce, we have selected a group of three photographs (kindly supplied through the courtesy of Professor Robley C. Williams of the Virus Laboratory). The first photograph (Figure 9) shows a number of tobacco mosaic virus (TMV) rods in their native state. By suitable treatment, these rods may be separated into solutions of protein

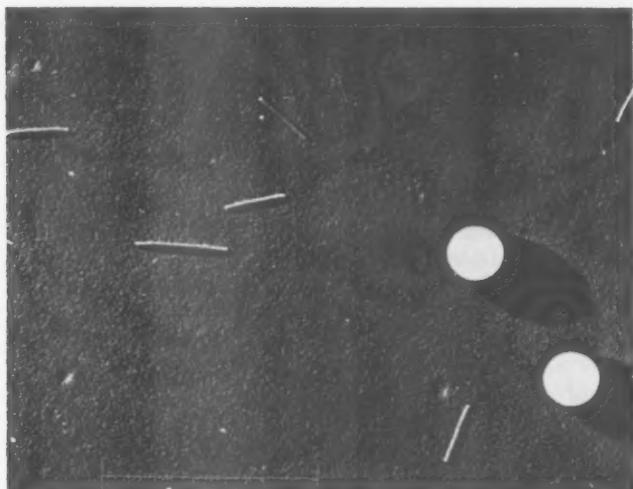


Figure 9. Native TMV



Figure 10. Repolymerized TMV protein

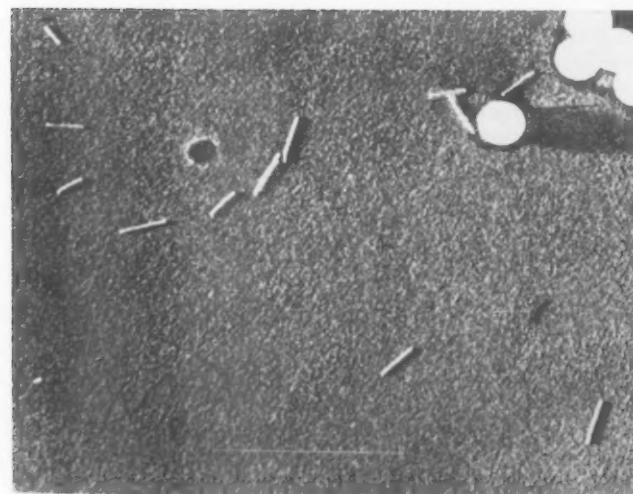


Figure 11. Reconstructed TMV protein and RNA

(approximately 95% of the rods) and ribonucleic acid (RNA) (approximately 5% of the rods). The RNA carries the information necessary for the reconstruction of more of the acid and the proteins by whatever cell the virus later infects; we will discuss this genetic control in the next section.

At the moment, we are concerned with the fact that when the protein part of the TMV is put back in the proper ionic strength and pH, the molecules will reassemble themselves into rod-like structures resembling very much the original, intact particles (Figure 10). Notice, however, that in the absence of the nucleic acid the protein assembles itself into rods of random lengths, and not of uniform lengths. Finally, if the nucleic acid which, as you will see later, contains the genetic information, is added back into the protein solution and then the pH and ionic strength are adjusted for reconstitution, particles are obtained which are practically indistinguishable from the original TMV particles, in both physical properties and biological activity (Figure 11). Thus we see how the macrostructure of visible cellular elements is implicitly contained in the microstructure of the molecules of which these elements are made.

While the knowledge of the interaction of giant molecules, or macromolecules, both synthetic and natural, has made great strides in the last decade or two, we are still only at the beginning of our investigation of systems of macromolecules of sufficient complexity to provide us with the kind of information we would like to have for the present purposes. However, it seems to me that already enough information is available to us to be able to say with confidence that the basic kinds of physical-chemical processes upon which we will have to draw in order to describe the evolution of the cellular structure are already at hand.

That characteristic which is most frequently invoked as the prime attribute of living material is the ability to reproduce and mutate. Very frequently in discussions of the origin of life, attempts are made to define that certain point in time before which no life existed and after which we may speak of "living" things, as that point at which there came into existence an organic unit, whether a molecule or something bigger, which could generate itself from existing precursors, and which could sustain and propagate a structural change. Since we can be confident that genetic information is transmitted today in the environment of a cell by the chemical substance known as desoxynucleic acid, of which we have already spoken, it seems reasonable to seek in this structure the clues to mutable self-reproducing molecule, or unit.⁽¹³⁾

It should be pointed out that while we are in the habit of thinking of the nucleoprotein molecules which constitute the chromosomes and viruses (DNA and RNA) as containing all the information required to produce an entire organism, this is not strictly true. These structures may be said to contain information only in relation to, and exhibitable through, a proper environment. Thus it is possible to keep a bottle containing only virus particles (say DNA) indefinitely, just as any other organic chemical, and the question of whether it is alive or not would not arise. The moment these particles find themselves in a suitable organic medium (such as may be found in any of a variety of cell cytoplasms), this information makes itself apparent and the virus multiplies. There are thus other constituents in the modern cell which contain indispensable information, but under direction of the nucleoprotein of the chromosomes.

While a chemical model⁽¹⁴⁾ operating in one dimension has been described, which is able to control the behavior of a mixture of precursor units as it goes on to form a larger material, it is only in recent months that the

ability has been achieved to separate the controlling, information-carrying units from the energy-transforming units, and to demonstrate that information can indeed be carried by the desoxynucleic acid particles.⁽¹⁵⁾

You will recall that the DNA, or chromosomal material, is made up of a linear array of only four units, represented in Figure 7 by the four bases (adenine, thymine, cytosine and guanine), and that the controlling information about the organism (at least a modern, post-Cambrian cell) is contained in some kind of linear array of these four units. In the past few years it has been possible to isolate from various living organisms, particularly bacteria, a catalyst (enzyme) which, when placed into a solution containing all four of these units in an active form—that is, as their triphosphates—was able to induce their combination into some particular linear array of bases to produce a particular variety of desoxynucleic acid. Which particular DNA was formed depended entirely upon the presence of a very small amount of "starter" which had to be added to this mixture. If this starter were obtained from one type of cell, that particular type of desoxynucleic acid would be formed; from some other type of cell, another type of DNA would appear.⁽¹⁶⁾

Still more recently, it has been possible to make a synthetic desoxynucleic acid, consisting of only two of these bases, in particular the thymine and adenine.⁽¹⁷⁾ This synthetic DNA presumably has no counterpart in nature today, and yet when this synthetic material is given as a "starter" to the reaction mixture, as previously described, that particular two-base desoxynucleic acid, made up of only thymine and adenine, is produced. The catalyst which is able to do this seems to be the protein-like material constructed of amino acids in the way proteins usually are. Although little is yet known about the nature of this catalyst it will almost certainly be related to the simpler compounds and elements whose more primitive catalytic abilities constitute the basis for its action. This is exactly analogous to the relationship between the catalytic ability of simple iron ions and that of the highly effective iron proteins, as described in Figure 4.

We have now traced the path from the primitive molecules of the primeval earth's atmosphere to the information-transmitting molecule which is capable of self-reproduction and variation. During the course of this process we have, naturally, made use of the organic materials which have been produced in high-energy form via various energy-yielding routes. In addition, somewhere, either during the course of this chemical evolution or perhaps succeeding it, a system was evolved in which the concentration of the reaction materials was retained in a relatively small volume of space, leading to the formation of cellular structures.

During this entire course we have made use of the randomly-formed molecules, followed by a chemical kind of selection. The ultimate production of the information-carrying molecules depended upon the preferred presence of their constituent units; for example, nucleoside triphosphates or "active" amino acids. It is clear that as the efficiency of transformation is increased by chemical or early biotic evolution, all of these precursors will have been used up, and a mechanism will have to be devised for the regeneration of those precursors by more specific chemical routes than those originally used. We can see these very specific biosynthetic routes in the living organism of today.

The last ten to twenty years, particularly since the application of tracer techniques, have exposed to use the wide variety of relatively complex biosynthetic sequences, of which we had an illustration in Figure 4, leading to the porphyrin, and which appear to be a

sequence of reactions directed toward a particular end. The usefulness of any intermediate step does not become apparent until the final product is formed. Such sequences, on an organismic level, have led to a variety of teleological theories about the nature of evolution. However, on the molecular level it is possible to see the way in which complex, apparently directed, biosynthetic sequences arose by the operation of the ordinary laws of physics and chemistry, including autocatalysis as the basis of selection.

This was pointed out by Horowitz some years ago when he recognized that once a useful material formed into an "organism" which could transmit its information to its offspring, this process would continue as long as precursors were available for this "organism" to use for its reproduction.⁽¹⁸⁾ However, eventually it was clear that one or another of these precursors would become exhausted. That particular organism which could adapt itself by a random variation to make the missing precursor from molecules which still remained available to it would, of course, survive, provided the knowledge of how it was done could be transmitted; all the others would die out. We now have lengthened the chain of synthesis by one step, but in a backward direction toward the simpler precursors. By extrapolating this back, eventually to carbon dioxide, one can get the very complex, and what appear to be totally directed, syntheses from the very simplest of all carbon compounds.

There remains one additional attribute which is always associated with living material and which is very frequently called upon as a prerequisite to life—namely, the ability to use energy-yielding chemical reactions to create order out of disorder. Ultimately, of course, the large-scale evolution of living organisms could not take place until the invention of photosynthesis; that is, the coupling of the ability of certain molecules to absorb solar energy, to the ability of certain other molecules to use this energy for the synthesis of the necessary structures. It is almost certain that the ability to synthesize had evolved long before the ability to couple the absorbed solar energy to those synthetic reactions. The use of porphyrins by nonphotosynthetic organisms is widespread, and almost certainly random variation in structure led to the discovery that small changes in the porphyrins, leading to the construction of chlorophyll and its use in transmitting energy for biosynthesis, led to the invention of photosynthesis.⁽¹⁹⁾

Strictly speaking, the primitive synthesis of which we spoke, making use of ultraviolet light or ionizing radiation, is a form of photosynthesis, and in all probability there existed a parallel evolutionary development of this kind of energy-conversion process. In fact, modern work by physical chemists⁽²⁰⁾ on the effect of the far ultraviolet light on some of the simple molecules we spoke of earlier as constituting the primitive atmosphere of the earth, has demonstrated experimentally the feasibility of the conversion of water (H_2O) into Hydrogen (H_2) and oxygen (O_2) by far ultraviolet. It has been possible to demonstrate the conversion of carbon dioxide (CO_2) into carbon monoxide (CO) and oxygen (O_2) using sunlight of such high energy that very little of it penetrates down very far into the present earth's atmosphere.⁽²¹⁾

Whether the conjunction of the use of visible light-absorbing substances, such as the porphyrins, with the biosynthetic demands of the more highly evolved chemical systems took place before or after the appearance of what we would today call living organisms, matters little for the purposes of our present discussion, important though the question may be. It seems quite clear, however, that these two parallel lines of development did

meet, as mentioned earlier, giving rise to very efficient energy conversion processes resembling those which we know today. It is likely that the final step in the development of modern photosynthesis, the evolution of oxygen, did not take place until relatively late in the sequence of events. For example, we have organisms today which are capable of using solar energy via the agency of porphyrin-type molecules, but use other methods of taking care of the oxygen by combination with suitable reducing agents such as hydrogen. They appear in the form of photoreducing organisms such as the photosynthetic bacteria. They dispose of the oxidizing fragment of the water molecule, made by the absorption of light, by combining it with whatever reducing materials may have been present in the primitive atmosphere. It is not until the higher green plants appear that we find the ability to dispose of this oxygen back into the atmosphere as molecular oxygen.

With this biological discovery the stage was set for the enormous development of living organisms on the surface of the earth as we know them today. From here on, the fossil record is quite complete and there is little point for us to pursue in detail the ascent and divergence of life, leading ultimately to mankind in the last million years.⁽²²⁾

It is perhaps worthwhile at this point to try to assess the amount of time which may be allotted to each of the major sequences of events which we have outlined as leading ultimately to cellular life as we know it on the earth today, and to man. Most of you are undoubtedly aware that from the very beginning the fossil record contains evidence of very nearly all of the major subkingdoms of life today. This fossil record, which is some 500 to 1000 million years old, thus indicates that by the time life was sufficiently well developed to leave such a record it had already manifested itself in nearly all of the major types of form which we now recognize. This time period constitutes something less than one-quarter of the entire habitable life span of the earth. Thus we have some two or three billions of years during which we can pursue the process of chemical evolution, overlapping that part of the evolution of cellular life (biotic evolution) which was unable to leave a record of itself in the rocks. This extremely long period of time gives us ample opportunity for the enormous numbers of trials and errors which would be required to develop all the possible molecular processes and combinations which must have been tried.

Undoubtedly, many different information-carrying molecular species had a birth, a life span and a death, much as we now see in the fossil record for the higher forms. One (DNA) or only a few eventually superseded all the rest, because of the particular structural, chemical and dynamic properties of this arrangement of atoms—stability, template or complementarity quality, mutability and others not yet defined. It was from this, or these, that the present-day organisms have developed, thus providing a basic similarity in all living processes as we know them today.

The determinism in the arrangement of a system increases with the number of trials that can occur in reaching it. On the molecular level, where the number of changes occurring per second is high, predictability with regard to what will happen in a given situation to a group of molecules amounts to certainty. For example, pressure maintained by bombardment of molecules on the walls of a vessel containing a certain number of gas molecules at a specified temperature is quite predictable. While we cannot specify the particular molecules which will strike the wall at any time, we can be quite sure

that in a given period of time a certain number will do so.

At the other extreme, the segregation and recombination of genes which may take place in the formation of a new individual by geologically modern genetic mechanisms appears as a completely undetermined, or random, choice, since only a single event is involved. However, among a group of organisms of a given species there will be a predictable distribution of properties at a given time under a specified set of conditions.

On the other hand, coming up from molecules and molecular aggregates, we will reach a stage, probably after the invention of cellular heredity based on nucleic acid, when the number of events (rate multiplied by time available) will not be large enough to ensure that all arrangements possible will have been tried, and an indeterminism with respect to those that have appeared will ensue.

Therefore, while an indeterminism exists with respect to the character of any individual living thing, and a limited indeterminism exists with respect to species, the time element is so great and the amount of genetic material which has been cycled through the sequence of birth, growth, development and death is so enormous,⁽²³⁾ that the certainty of the occurrence of cellular life as we know it on earth today seems assured, given the initial starting conditions.

A most convincing demonstration that such a sequence of events, leading from nonliving matter to life, could, and probably did, take place, would be an experiment in which a system of organic material, called alive by most biologists, is produced through the agency of no other life save the hand of man.⁽²⁴⁾ And already today there is serious discussion as to whether some of the experiments performed in the last year might not fulfill these conditions.

It thus appears that man is a rather late and highly developed (perhaps the most highly developed) form of that organization of matter which we call living, on the surface of the earth, and which is the result of the peculiar and special environmental situation provided on the surface of the earth since its formation some five billion years ago. We have known for some time now that the earth is the number three planet in orbit around a rather ordinary star on the edge of one of the minor galaxies of the universe. Thus, if we presume that life is a unique occurrence limited to the surface of this one rather trivial (in terms of mass, energy, position, etc.) planet, it appears that man, though an impressive representative of the state of matter called living, cannot be regarded as a major cosmic force.

What are the probabilities that cellular life as we know it may exist at other sites in the universe than the surface of the earth? In view of the chemistry of carbon (and a few of its near neighbors) and the consequences this has given rise to in the environment to be found on the surface of the earth, all that is required to provide some kind of answer to this question is an estimate of the number of other sites, or planets, in the universe which may have the environmental conditions to support such life.

Here we follow Shapley^(6a) (as well as others^(6b)), who begins his calculation with an estimate of the minimum number of stars which might be in the universe. His minimum calculation, based upon the best telescopes we have today, is of the order of 10^{20} ; that is, one with twenty zeros after it. The next step is to determine what fraction of these stars will have a planetary system. To make this estimate one must have some concept of how our planetary system was generated. Here there are

many theories and Shapley lists 14 to 15 of them. However, a number of conditions must be fulfilled; these, taken together with the fact that the universe must have been much more crowded than it is today, give the figure one in a thousand as a very conservative estimate of the number of stars which have a planetary system.

The next question which Shapley attempts to answer is what fraction of these planetary systems will contain a planet at approximately the correct distance from its star so that it will have a temperature variation compatible with the cellular life that we are seeking to determine. Here again we arrive at the very small, and what we consider conservative, figure of one in a thousand. The next circumstance which must be fulfilled is that of size. The planet must be of the correct size to retain an atmosphere, and yet not be too large. Once again Shapley gives the figure of one in a thousand as a conservatively small fraction.

Finally, of all of these planets which are the correct size, how many will have the proper atmosphere (containing carbon, hydrogen, nitrogen and oxygen) required to give rise to cellular life as we know it on earth? The answer is, again, the very conservative number of only one in a thousand.

Thus, we have four factors of 1/1000 by which we must multiply our original figure of 10^{20} . This leads to the number 10^8 , or one hundred million, as the number of habitable planets to be found in the universe. Remember that this calculation is limited to those planets which have conditions within the range compatible with cellular life, based on carbon, as we know it on earth. This does not include life systems, which conceivably we can imagine, based on other elements such as silicon, or nitrogen, or perhaps even anti-matter. Such worlds and such systems may very well exist. However, these are not included as possibilities in this calculation. The figure remains, then, at 100,000,000 planets which can support cellular life as we know it on the surface of the earth.

Because the time element seems to be about the same for all parts of the universe—namely, something greater than five billion years, we can be reasonably certain that these hundred million other planets will indeed have cellular life on them. Man's tenure on the surface of the earth has occupied only a very small fragment of time (only one million years of the five billion). On another planet his evolution might have been earlier or later by a substantial fraction of geologic time. Therefore, it is clear that we may expect to find cellular life, and perhaps precellular and post-human life, on many of these other planets. This does not deny the possibility of the existence of still other forms of matter which might be called living, but which are foreign to our experience.

By answering our second question in this way, we have now removed life from the limited place it occupied a moment ago, as a rather special and unique event on one of the minor planets around an ordinary sun at the edge of one of the minor galaxies in the universe, to a state of matter widely distributed throughout the universe. This change induces us to re-examine the status of life on the surface of the earth. In doing so we find that life on the surface of the earth is not a passive, existing thing, but that it actually changes and forms the environment in which it grows. The surface of the earth has indeed been completely transformed in its character by the development of the state of organization of matter which we call life. Furthermore, it is undergoing another, and perhaps a more profound transformation, by one representative, or manifestation, of that organization of matter—mankind.

Now that man has the capability of taking his machines and himself off the surface of the earth and of beginning

to explore outer space, there is no reason to suppose that life, and man as its representative, will not transform any planet, or any other astral body upon which he lands, in the same way, and perhaps even in a more profound way than he has transformed the surface of the earth. For example, it might suit him in the future to change the orbit of the moon, and it seems within the realm of possibility that he should be able to do so. When we realize that other organisms may be doing similar things at some millions of other regions in the universe, we see that life itself becomes a cosmic influence of significant proportions; and man, as one representative of that state of organization of matter, becomes a specific cosmic influence himself. Thus we have come to a complete inversion of our view of the place of life and of man from a trivial to a major cosmic influence. And we have come to this view entirely upon the basis of experimental and observational science and scientific probability.

Man's adventure into space, which is about to begin, is not merely a flexing of muscles, a demonstration of strength. It is a necessary aspect of evolution and of human evolution in particular. It is an activity within the capability of this complex organism, man, and it must be explored as every other potentially useful evolutionary possibility has been. The whole evolutionary process depends upon each organism developing to the greatest extent every potential.

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THE NAVY PROPELLANT RESEARCH

(Continued from page 4)

have the advantage of greater simplicity in design and therefore possibly greater reliability. However, problems exist in the fact that monopropellants which contain both oxidizer and fuel within a single composition can under certain conditions become unstable and decompose explosively. Further work is required in studying the problems associated with this type of instability and with the development of monopropellants which can be utilized under service conditions.

HYBRIDS:

A more recent interest of the Navy which is receiving strong emphasis and support is the hybrid rocket engine system. A hybrid motor is a liquid-solid propulsion thrust unit which is in essence combines liquid and solid technology with the purpose of realizing major gains in performance, reliability, cost, reduced development time and increased flexibility. It is based on the use of liquid and solid propellant components either of which could be the oxidizer or fuel. The Navy has sponsored some of the earliest work in this field and is currently pursuing several approaches simultaneously with the purpose of advancing the state of technology and service in this field as quickly as possible.

Hybrid Advantages

Among some of the more basic advantages of hybrids are the fact that (a) new liquid or solid propellants, as well as the standard ones, can be utilized to full advantages in an almost infinite variety of combinations, even those previously proven to be incompatible; (b) increased safety because of the modified or separate storage of high energy combinations; (c) optimization of specific impulse and density impulse according to the needs of a specific mission; (d) retention of on-off restart capability, full thrust throttling and other advantages of the liquid rocket engine rocket system.

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The hybrid concept also permits a way of minimizing some of the major problems of high-performance solid rocket systems, such as nozzle cooling, burning rate control, and limitations on mechanical properties.

Because of the nature of the hybrid system, research in this field can utilize to advantage much of present day knowledge in the liquid and solid rocket technology. Although superficially the hybrid represents a marriage of liquid and solid technology, such is not completely the case; there are introduced thereby new phenomena and problem areas which were not previously encountered in either liquid or solid power plant developments and which had to be more closely defined. These broad areas are:

- a. Solid-liquid phase chemical kinetics and the combustion processes intimately connected therewith.
- b. Research and development of propellants specifically tailored for the hybrid rocket engine.
- c. Establishment of the feasibility and design criteria for hybrid engines and the advancement of the hardware state of the art.

Investigation of each of these in turn can make significant contributions to the development of the hybrid engine and to its full utilization in the defense arsenal.

SUMMARY:

The preceding review of the Navy propellant research program was presented with the purpose of outlining some of the more significant accomplishments achieved by the Navy to date and to set forth the directions which the Navy is planning to go to achieve the state of propellant technology necessary to satisfy its future requirements. The Navy is proceeding with a broad plan not only with respect to the items discussed here but on other problems related to propulsion designs, advanced motor concepts and fundamental ballistics. It is anticipated that the next decade will see major changes in propulsion technology resulting from the use of more energetic propellants and from the development of advanced motor designs integrating new concepts in nozzles, thrust vector and magnitude controls and advanced materials and case fabrication.

100TH WINS AGAIN

For the first time since the award was established at the end of 1959, the U.S. Army Chemical Corps Training Command quarterly Commander's Honor Unit trophy has been won twice by the same unit.

And it was twice in a row for the 12th Chemical Company (Maintenance), 1st Chemical Battalion (Service), 100th Chemical Group, when the big trophy and plaque were presented in recent ceremonies, at Fort McClellan, Ala.

The occasion also marked the third time in succession the honor had been won by a 1st Battalion unit and the fourth award out of five to a unit of the 100th Group, the Chemical Corps' largest troop unit.

The commander of the 12th, Capt. Robert D. Doverpike, and the first sergeant, M/Sgt. Harley P. Mowery, accepted the award for the company from Col. William H. Greene, commanding officer of the Training Command.

The job of the 12th is to stand ready to perform, under combat conditions, both the field and base-type maintenance required by the quantity of Chemical Corps material that would be used by as many as 100,000 troops.

WHAT THE BUSINESS MAN SHOULD KNOW ABOUT THE LAWS OF FOODS, DRUGS AND COSMETICS

(second of two parts)

By VINCENT A. KLEINFELD

The Poultry Products Inspection Act

ALTHOUGH MEAT AND meat products moving across state lines were required to be inspected under the Meat Inspection Act after 1906, poultry was not subject to compulsory federal inspection. For a number of years those engaged in marketing poultry could obtain such inspection if they desired it, but there was no law compelling inspection.

The sanitary conditions in some plants, consequently, were quite unsavory. Many consumers, learning of this situation, avoided poultry products, particularly in restaurants. The problem was forcefully brought to the attention of Congress, however, by representatives of the workers in poultry establishments, for, due to the unsanitary conditions, some workers developed a disease from infected poultry. The result was the passage in 1957 of the Poultry Products Inspection Act.

Effective January 1, 1957, any establishment slaughtering poultry for transportation or sale in interstate commerce must obtain federal inspection. With certain limited exceptions, all dressed poultry or poultry products shipped in interstate or foreign commerce must be inspected. The term "poultry" includes chickens, turkeys, ducks, geese, and guineas.

The Act also provides that following a request from state or local officials or local poultry industry groups, and under certain conditions, the Secretary of Agriculture may "designate" cities or areas where he has reason to believe that poultry or poultry products, although they may not move across state lines, are handled or consumed in such volume as to affect the movement of inspected poultry products in interstate commerce. These designated cities or areas are known as "designated major consuming areas" and are subject to such provisions of the statute as the Secretary of Agriculture may prescribe.

The Poultry Products Inspection Act is administered by the Inspection Branch, Poultry Division, Agricultural Marketing Service of the Department of Agriculture. It is the responsibility of each processor who is required to have inspection service to make application to the Department for inspection.

Inspection consists of an examination of each bird processed to determine its wholesomeness and fitness for food, maintenance of prescribed sanitary standards, and supervision of the preparation, processing, labeling and packaging of poultry products. Thus, consumers who buy inspected poultry and processed poultry products bearing the federal inspection mark can be assured (as in the case of meat and meat products inspected under the Meat Inspection Act) that their poultry meat comes from healthy birds processed in sanitary surroundings and that it is labeled truthfully. Those who violate the Act are subject to fine and imprisonment.

The Virus, Serum, and Toxin Act

The Federal Food, Drug, and Cosmetic Act provides specifically that nothing contained in that law shall be construed as affecting or modifying the provisions of the Virus, Serum, and Toxin Act. That extremely important statute in the field of the protection of public

health was passed in 1902, is now incorporated in the Public Health Service Act, and is administered by the Public Health Service of the Department of Health, Education, and Welfare.

The statute controls the manufacture of what are known as biological products—described in the law as any virus, therapeutic serum, toxin, antitoxin, or analogous product. For example, the marketing of life-saving drugs such as the smallpox vaccine and the Salk vaccine for polio is regulated by this law. Briefly, the statute provides that no one shall distribute in interstate commerce, or import or export, any virus, serum, toxin, antitoxin, or other product, applicable to the prevention, treatment or cure of diseases or injuries of human beings, unless the product has been prepared at an establishment licensed by the Secretary of Health, Education, and Welfare. Each package of the drug must be plainly marked with the name of the drug, the name, address, the license number of the manufacturer, and the date beyond which the contents cannot be expected beyond reasonable doubt to yield their specific results. Employees of the Department of Health, Education, and Welfare may inspect establishments preparing such products at all reasonable hours.

Licenses for the maintenance of establishments preparing the products covered by the Act are issued only upon proof that the establishment and the products for which a license is desired meet standards designed to insure the continued safety, purity and potency of such products. These standards are prescribed in regulations made jointly by the Surgeon General of the Public Health Service and the Surgeons General of the Army and Navy and approved by the Secretary of Health, Education, and Welfare, and licenses for new products may be issued only upon a showing that they meet the standards. Those who violate the law are subject to fine and imprisonment.

An example of how the law operates is the Salk vaccine against infantile paralysis. In the spring and summer of 1954, a large-scale field trial of a new vaccine against polio, developed by Dr. Jonas E. Salk, of the University of Pittsburgh, was conducted under the auspices of the National Foundation for Infantile Paralysis. A scientific committee which had been created to evaluate the results of the trial reported that the vaccine, used on more than 450,000 children in 44 states, had been safe and effective in substantially reducing the risk of paralytic polio. Upon recommendation of the Public Health Service, the Secretary of Health, Education, and Welfare, under the provisions of the statute, licensed six manufacturers to produce the Salk vaccine.

During the following spring, cases of polio were reported among children who had received the vaccine manufactured by one of the producers. Apparently because controls and procedures were not sufficient, a small number of children developed polio. As a result, the Public Health Service requested withdrawal of the manufacturer's product and conducted an investigation of the production and testing of the vaccine. This review led to revisions in the requirements for manufacturing and testing the Salk vaccine, closer observation of the

manufacturing processes, and the initiation of a research program in the development of the vaccine. The data indicated that the cases associated with the vaccine produced by one manufacturer had the characteristics of a common source epidemic, and that the development of polio in some children was the result of the presence of live polio virus in some lots of the vaccine prepared by the manufacturer.

The question may well be asked why the revisions and more rigid safeguards and observations of the manufacturing processes were not put into effect earlier by the Government, or why the Government did not request manufacturers of the vaccine to submit samples of each batch to the Government for examination, at least during the first year. It is interesting to note that, in civil suits for damages instituted by the parents of some children who had been stricken by polio after the use of the vaccine produced by the manufacturer in question, large verdicts were awarded by the juries. These verdicts were awarded, however, not on the basis of negligence on the part of the manufacturer, but rather on the basis that, when the manufacturer distributed the vaccine there was an implied warranty (which amounted to a contractual obligation) that the vaccine did not have live polio virus that could infect the children. These judgments against the manufacturer are being appealed.

The Federal Trade Commission Act

The Federal Trade Commission has a number of important functions. It possesses the over-all responsibility of stopping illegal business practices which deceive the public or threaten fair competition in interstate commerce. I shall discuss here the function of the Commission in the advertising of foods, drugs, devices and cosmetics, and not its function in the fields of anti-trust and monopoly and unfair competition.

The Federal Trade Commission protects the consuming public from being deceived in its purchase of foods, drugs, devices and cosmetics advertised or sold across State lines. This type of antideceptive activity also incidentally protects honest manufacturers and distributors of these products from the unfair advantage possessed by their competitors who choose to engage in fraudulent or deceptive advertising.

The Federal Trade Commission is composed of five commissioners appointed by the President and confirmed by the Senate, of whom no more than three may be of the same political party. The original Federal Trade Commission Act of 1914 prohibited "unfair methods of competition in commerce." In 1931, the Supreme Court held that the Commission could not proceed unless it established that the deceptive acts complained of caused injury to competition. In 1938, amendments were passed to give the Commission authority to proceed against "unfair or deceptive acts or practices in commerce" as well as "unfair methods of competition in commerce," so that orders of the Commission may be issued without the necessity of proving injury to competition.

These amendments also conferred special authority in the Commission to control the advertising of foods, drugs, devices and cosmetics. When necessary for the protection of the public interest, the Commission is authorized to obtain temporary injunctions against the false or deceptive advertising of foods, drugs, devices and cosmetics pending completion of the cease and desist order proceedings. Where the product advertised may be injurious to health or the advertising has been disseminated with a fraudulent intent, criminal prosecution may be brought by the Department of Justice upon the recommendation of the Federal Trade Commission. Upon conviction the defendant may be fined \$5,000 and sentenced to six

months' imprisonment, or double this fine and imprisonment for a second offense. The Commission seeks criminal prosecution, however, in extremely few instances. This is one of the important differences in this field between the Commission and the Food and Drug Administration.

The Commission customarily proceeds by issuing a complaint against someone alleged to have engaged in false or deceptive advertising. The complaint seeks to require the respondent to cease and desist from continuing to disseminate the false or deceptive advertising. Sometimes, even before the issuance of a complaint, a stipulation is signed under which the respondent agrees that he will refrain from the advertising. After a complaint is filed, the respondent frequently comes in voluntarily and consents to a cease and desist order. When the respondent does not do this, hearings are held before an examiner, frequently in various cities throughout the country, and witnesses for the Government and the respondent are examined and cross-examined under oath by counsel for both sides. The proceedings are rather formal in nature and quite similar to those before a judge and jury.

The procedure of the Commission in holding hearings in various cities, although convenient for witnesses, may create a serious financial burden upon litigants. This is presumably one reason for the numerous stipulations and consent orders which are agreed to by respondents—at times they simply cannot afford the legal fees and other expenses necessitated by the lengthy proceedings in many cities.

The Federal Trade Commission Act contains an extremely important provision with respect to foods, drugs, devices and cosmetics. This states (and there is generally similar language in the Federal Food, Drug, and Cosmetic Act dealing with labeling) that in determining whether any advertisement is misleading, there shall be taken into account not only representations but also the extent to which the advertisement affirmatively fails to reveal facts material in the light of the representations. For example, suppose a product is advertised for baldness. It may be effective for a very limited type of baldness. If it is held out for baldness in general, the Commission will not only prohibit the manufacturer from advertising that his product is helpful in all kinds of baldness, but may also compel him to reveal in his advertising that the majority of cases are caused by age and male pattern baldness and that the preparation is not effective in such cases.

A respondent may seek review by a United States Court of Appeals from a cease and desist order of the Federal Trade Commission. If the court affirms the order, or sixty days after the issuance of the order if no appeal is taken, the order becomes final. Until this occurs the respondent may not be unduly concerned, for he is not actually being punished for his past transgressions but being directed not to do it again. Once the cease and desist order has become final, however, it is most important not to violate it. This is because in the event of a violation of the order a civil penalty suit may be instituted by the Government seeking up to \$5,000 for each offense, and each separate advertisement during each day of a continuing violation may be treated as a separate offense.

The Insecticide Act

The Federal Insecticide, Fungicide, and Rodenticide Act, commonly referred to as "the Insecticide Act," is designed to protect those who use insecticides, fungicides and rodenticides, weed-killers and disinfectants, known as "economic poisons," from ineffective or unsafe products of this character.

An "economic poison" is a substance intended to prevent, destroy, repel or mitigate insects, rodents, fungi,

bacteria and weeds. "Fungi" includes molds, yeasts and bacteria except those on or in living man or other animals. Typical examples of fungicides are preparations intended for disinfecting premises to prevent the spread of disease, products offered for the prevention of the growth of bacteria and molds, and substances intended to prevent rot or decay by resisting the growth of organisms causing rot or decay.

The law requires that the labeling of an economic poison contain directions for use which are adequate for the protection of the public. The directions must be such that the product will be effective for the intended purposes and will not be harmful to man or beneficial animals when used as directed. The label must bear necessary warning or caution statements, and any product which contains an ingredient in a quantity highly toxic to man must bear on the label the skull and cross-bones, the word "poison" prominently in red, and the statement of an antidote for the poison. Certain white powdered economic poisons, such as lead arsenate and sodium fluoride, must be distinctly colored or discolored so as to prevent their being mistaken for common white powdered foods such as sugar, salt, flour, or baking powder. The reason is obvious. Many fatalities occurred in the past because people mistook a poison such as sodium fluoride, used to kill rats, for an ingredient of food.

The Act contains a very strong weapon for consumer and industry protection in requiring that all economic poisons must be registered with the Department of Agriculture before being shipped in interstate commerce. When a manufacturer wishes to register an economic poison, he must submit to the Department of Agriculture an application of registration, together with duplicate copies of the proposed labels, as well as circulars and other advertising material, together with a statement of any other claims to be made for the product and directions for use. Unless the information appears on the label submitted, there must also be furnished to the Department a statement of the name and percentage amount of each active ingredient of the economic poison and pertinent information concerning the other ingredients and the physical properties of the product. If a product and its proposed labeling, after examination by the appropriate technical personnel, appear to be in full compliance with the requirements of the statute, registration is issued by the Department. Registration, however, is primarily a device to bring the economic poison to the attention of the Department of Agriculture and to furnish an opportunity to correct obvious faults in labeling. Although the registration is made after careful consideration by the Department, as a matter of law the registration is not an approval of either the product or its claims by the Government. The manufacturer is responsible for the compliance of his labeling with legal requirements. Further, the Act does not permit the fact that registration has been issued to be used as a defense in case of a violation of the law, and the manufacturer is not permitted to place on a label a statement that the product is registered.

If a product or its labeling does not appear to comply with the law, the manufacturer is informed of the objections and given an opportunity to make necessary corrections. In the event the information he has submitted is insufficient, so that proper consideration cannot be given to the labeling, he is asked for more information. For example, he may be asked for the results of experimental work disclosing both the safety and effectiveness of his product.

The Act contains a provision to the effect that the penalties named in the law shall not apply to a manufacturer or shipper of an economic poison for experimental

use only if a permit is obtained from the Department of Agriculture before a shipment is made. Consequently, when the manufacturer of a new economic poison has carried out sufficient laboratory tests to make him think it may have commercial possibilities, and he wishes to have it tested on a larger scale, he may request a permit to ship the product for experimental use. To obtain such a permit he must submit the following information: the name and address of the shipper and the places from which shipment will be made, the proposed shipping period, identification of the material to be covered by the permit, approximate quantities to be shipped, the types of tests, a statement that the product is intended for experimental use only, the proposed labeling of the product, and a statement certifying that the economic poison is to be used for experimental purposes only and that to the best of his knowledge the persons to whom it will be shipped are qualified to do the experimental work. In the event the manufacturer subsequently believes that he has sufficient information about his product to justify its registration, he submits all of the information relative to its effectiveness and toxicity to the Department of Agriculture.

The Act contains a somewhat unusual provision. If a manufacturer disagrees with the criticisms of his proposed labeling by the Department of Agriculture, he may demand a "registration under protest," which must be granted. The effect of a registration under protest is to increase the possible penalties if the manufacturer should be found guilty of a violation of the law by reason of the factors to which objection was taken by the Department of Agriculture. There have been very few registrations under protest.

The Act authorizes the Department of Agriculture to cooperate with the agricultural or other regulatory agencies of the various states in carrying out the provisions of the Act and in securing uniformity of regulations. In accordance with this authority, very close contact is maintained with the state enforcement agencies. The Department has participated in the preparation of a proposed Uniform State Economic Poisons Act, which in some form or other has been passed by a majority of the states. When new chemicals are registered under the Act as economic poisons, it is the policy of the Department of Agriculture to notify state officials desiring such notification of the fact of registration. Even though federal registration is secured, it is nevertheless necessary to register the product in each state whose law requires registration.

A tremendous number and variety of products are subject to the jurisdiction of the statute. It covers not only products designed to kill insects and rats or which are to be used against plant diseases or to kill weeds, but also preparations marketed for the purposes of sterilizing or disinfecting materials, equipment, clothing, etc. For example, preparations intended for disinfecting premises to prevent the spread of disease and for disinfecting food-handling and dairy equipment, surgical instruments and barber and beauty shop utensils are encompassed by the statute. As in the Federal Food, Drug, and Cosmetic Act, it is the intended use of a product that may bring it within the scope of the Insecticide Act. Determining such use is therefore of vital importance. The intent is not derived solely from an examination of the claims and directions for use on the label of a product, but also from representations made in typical advertising media, such as in newspapers and magazines and by radio or TV, and even of statements made by the manufacturer or distributor of the product. In one case, a product called "Kitchen Klenzer," for scouring sinks and kitchen utensils, was held to be a

fungicide by virtue of the fact that the label claimed that the product would remove germs and had an anti-septic action. It was the intended use, falling within the definition of "fungicide" in the Act, which brought the product within the purview of the statute. The fact that the product would not, in fact, kill fungi did not remove it from the classification of "fungicide."

Thus, when materials have been treated so that the materials themselves are protected from fungi, they will not fall within the classification of economic poisons, but if the intended use of the treated materials discloses that their purpose is to repel bacteria or fungi on textiles, paints or other products, then the materials would be covered by the Act.

A typical example is paper which has been treated so that it will be resistant against mildew. The paper would not be classified as an economic poison. However, if by means of representations, wherever they appear, the treated paper is marketed to protect a food product against spoilage by fungi, the treated paper would fall within the category of an economic poison. The problem is highlighted by a situation existing with respect to paints. If a chemical has been added to a paint to make the paint mildew-resistant, and the paint is held out as being mildew-resistant, the paint would not come within the scope of the Act. But as soon as a paint is represented as being capable of protecting other materials from decay by, or to prevent the growth of, fungi or bacteria, or to give protection to persons against germs, the paint would be an economic poison.

At the peril of laboring the point unduly, I want to repeat that to a large extent the problem is one of semantics. If I claim that my product is germ resistant or bacteria proof, this would not automatically bring it within the coverage of the Act. But if the labeling or advertising of my product, whether it is a paint, textile, or any other commodity, represents that the product protects other commodities or persons against bacteria or fungi, then my product is an "economic poison." If my laundry materials are held out simply as having been sterilized or disinfected by some process, they would not be covered by the statute. But if an article of clothing is offered for the purpose of affording continuing hygienic protection to the purchaser during use, the article is covered by the Act. Stockings treated with a substance to help prevent athlete's foot, and diapers and bed pads treated to combat bacteria, and offered for these purposes, are "economic poisons." Endless examples can be given, but as indicated, it is the intent of the manufacturer or distributor, as evidenced by his representations, that determines the question whether the Insecticide Act comes into play.

Recent Amendments

On July 12, 1960, President Eisenhower signed into law two important bills relating to the Food and Drug Administration. One of these was a direct amendment to the Federal Food, Drug, and Cosmetic Act and deals with "color additives." The other, denominated the "Hazardous Substances Labeling Act," is not a part of the Federal Food, Drug, and Cosmetic Act itself, but is to be administered by the Food and Drug Administration.

The Color Additive Amendments of 1960 broaden the authority of the Food and Drug Administration with reference to colors used in foods, drugs and cosmetics. Previously, the only colors which had to be "cleared" through the Agency were coal-tar colors. Such colors, commonly referred to as "certified colors," were permitted in foods, and most drugs and cosmetics, only if they were completely harmless and certified by the Government. The new amendment requires every "color

additive" (defined as any substance capable of imparting color to a food, drug, cosmetic or the human body) to be cleared through the Food and Drug Administration before it can be used. The criteria for use of these colors relate primarily to satisfy, but also involve the question of deception. Thus, the colors must be demonstrated to be safe, and it also must be proven that their use will not result in deception of the consumer. Because of the large number of colors that must be cleared through the Food and Drug Administration, Congress granted a general two-and-one-half year grace period to comply with the new amendment.

The Hazardous Substances Labeling Act in effect requires that many commonly used household articles, which have the capacity to cause substantial injury or illness, bear adequate labeling statements warning against the hazardous attributes of the articles and providing information for first-aid treatment.

Included within the broad definition of hazardous substances are articles which are "toxic," "corrosive," "irritants," "strong sensitizers," "flammable" or which generate "pressures through decomposition, heat, or other means." These terms are more specifically defined in the law. Excluded from the definition are foods, drugs and cosmetics, economic poisons subject to the Federal Insecticide, Fungicide, and Rodenticide Act, and substances intended for use as fuels when stored in containers and used in the heating, cooking, or refrigeration systems of a house.

It can be seen that the main thrust of this statute is to provide the consumer with information relating to the dangers of use and misuse of the substances covered. The Act is intended to reduce the hazards of such use by providing adequate warnings and other information.

Sanctions available to the Government for violation of the Hazardous Substances Labeling Act include seizure of the offending article, injunctions, and criminal prosecution of the parties responsible for a violation. Congress gave the affected industries until February, 1961, to comply with the labeling requirements of the Act, but this time can be further extended by the Secretary of Health, Education, and Welfare through January, 1962.

ARMY CENTERS RESEARCH IN BASIC SCIENCE AT DUKE

The Army Research Office-DURHAM is now operating on a service-wide basis to monitor and support basic research in the physical science field for all Army Technical Services.

The Office and its programs will be increased, according to Lt. General Arthur G. Trudeau, to meet new functions which have become its responsibility.

Under Ordnance management the Office has financed and managed basic research with universities, colleges, other institutions and private firms. One hundred and twenty-five of these contracts were listed in the November-December issue of the *Journal*.

Col. George W. Taylor is the Commanding Officer and Dr. John W. Dawson, Chief Scientist. Dr. J. Deryl Hart, President of Duke University, said he was pleased at the transfer of the old Office into an Army-wide status.

The Office of Ordnance Research was established by the Ordnance Corps in space leased from Duke University nine years ago.

COMPANIES

Merck & Co., Inc. has announced that the Merck Sharp & Dohme International Division will spend half a million dollars this year to expand its Morson chemical manufacturing facilities at Ponders End, England. This brings to \$1.5 million the company's investment at this plant since acquiring Thomas Morson & Son, Limited, in 1957.

Monsanto Chemical Company, which formerly owned 50 percent of Chemstrand Corp., acquired the remaining 50 percent from American Viscose Corp. early this year. With this acquisition, the report states, Monsanto is now the third largest domestic chemical company in regard to sales, which include Chemstrand.

Monsanto Chemical Company is increasing the capacity of its high-pressure polyethylene plant at Texas City.

Republic Aviation Corp. has started an expansion of its plasma propulsion activities that will embody the doubling of laboratory personnel and the building of one of the largest electrical propulsion testing facilities in the country.

The Dow Chemical Company plans to build a second polyolefin plant at its Louisiana division at Plaquemine.

The Carborundum Company will construct a million dollar coated abrasive manufacturing plant at Melbourne, Australia.

Columbia University recently signed an agreement to operate the Industrial Reactor Laboratories, a nuclear research facility at Plainsboro, N. J., which is owned by ten industrial corporations. Dr. Robert Wayne Houston, professor of Chemical Engineering, has been appointed laboratory director.

Research at IRL covers a broad range from basic physical and chemical research to development activities. Most of it centers on radiation damage, potentially useful chemical or physical effects, neutron and nuclear physics and radioisotope production. IRL is jointly owned by American Machine & Foundry Co., The American Tobacco Co., Atlas Powder Co., Continental Can Co., Inc., Corning Glass Works, National Distillers & Chemical Corp., National Lead Co., Radio Corporation of America, Socony Mobil Oil Co., Inc., and United States Rubber Co.

A large-scale field trial of a new measles vaccine developed by Chas. Pfizer & Co., Inc., was begun this week in Buffalo, N.Y., by the Erie County Health Department and the University of Buffalo Medical School. Some 750 children, all kindergarten and first-grade pupils in 15 public and parochial schools, have received the first of three shots in a double-blind study.

The Borden Co. and the United States Rubber Co. have announced the formal organization of Monochem, Inc., a jointly owned company which will construct a major chemical complex in the Baton Rouge area to convert hydrocarbons into more than a dozen chemical products.

Thiokol Chemical Corporation has recommended to the National Aeronautics and Space Administration the development of a three-million-pounds-thrust solid rocket motor for use in a manned space vehicle.

DIED

Of a heart attack on 7 August 1960, Colonel James C. Sawders, at Briarcliff Acres, Myrtle Beach, S. C.

ELECTRICITY FROM FUSION

An experimental facility (DCX-2) to produce temperatures in billions of degrees is planned for operation this fall at Oak Ridge as a part of the effort to control fusion reaction and provide man with an unlimited source for electric power.

The DCX-2 is a facility using a "hot ion" injection system. The so-called "hot" ions are atomic particles electrically charged and accelerated by high voltages before being introduced into the device. Ions in the DCX-2 will have the energy of 600,000 electron volts, comparable under some conditions to temperatures of more than three billion degrees centigrade.

Oak Ridge National Laboratory is operated by Union Carbide Corporation for the Atomic Energy Commission. ORNL is fabricating components of the DCX-2 which are highly specialized. Heavy Construction and installation are being done by H. K. Ferguson Company. Cost of the project is estimated at \$1.6 million.

The DCX-2 contains improvements over the DCX-1, which has been in operation for the past three years.

Fusion is the fusing together of nuclei of the lighter elements as opposed to fission, the splitting of nuclei of heavier elements. Each time two nuclei fuse, energy is released. This is the reaction that occurs on the sun and extremely high ignition temperatures are required.

Deuterium, a heavy form of hydrogen, is a material that offers promise in fusion reactions. It is readily available in sea water, and if the reaction can be controlled, energy producing would be, AEC states, essentially unlimited.

THE COLLOQUIUM

The studies or papers of the two distinguished scientists, Dr. Harold C. Urey and Dr. Melvin Calvin, which appear in this issue of the *Armed Forces Chemical Journal*, were subjects introduced at the Lunar and Planetary Exploration Colloquium which meets from time to time, usually in Los Angeles.

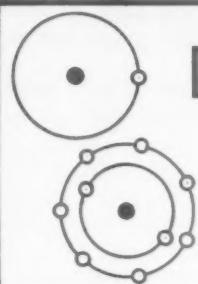
It is an informal gathering for discussion of scientific and engineering aspects of lunar and planetary exploration. It is not intended to replace any other organization or to impinge on the prerogatives of any agency or group, governmental or otherwise.

Those who attend the meetings hope to provide a forum for the unification, clarification, and cross-fertilization of ideas that may benefit, not only the members, but national technology as well.

S. M. Grenfield, who is with the Air Force Directorate of Research and Technology, has served as a member of the Steering Committee, and so has Doctor Urey.

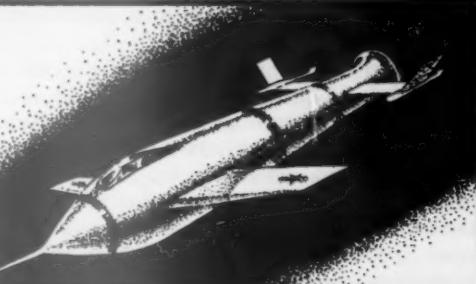
Doctor Urey is teaching at the University of California at La Jolla, and Doctor Calvin is teaching at the University of California at Berkeley. In addition to granting the *Journal* permission to print their stories, both gentlemen were kind enough to supply the original illustrations.

Proceedings of the Colloquium were printed in limited edition by North American Aviation, Inc., primarily for those in attendance or directly interested in affairs of the group. The editor of the *Journal* thanks Mr. Ray Berry of North American for his help on behalf of the *Journal* readers.



DEFENSE CHEMISTRY IN THE NEWS

WILLIAM T. READ, SR.



INORGANIC CHEMISTRY

metal production gives an encouraging outlook for the future in this field. In the steel industry out of a total of 3.76 million tons of chemicals, oxygen accounted for 1.43 million tons, lime 1.20 million tons, and acids 0.88 million tons. The demand for oxygen is expected to double in 10 years, but wider use in blast furnaces and cheaper oxygen may result in still higher demands. About one half of all oxygen is now used in open hearth furnaces, 23% in cleaning steel surfaces, and only 13% in blast furnaces. Calcined petroleum and coal tar pitch represent the major materials used in producing aluminum, but caustic soda, soda ash, ergolite and aluminum fluoride together total 864 million pounds. While tonnages are small, magnesium, beryllium and uranium account for considerable quantities of heavy metals. The entire metals industry, of which production is a small part, accounts for still much larger amounts of chemicals.¹

An impending world-wide shortage of fluorine has led to a number of improvements in various processes for recovery of this element in the form of hydrogen fluoride. Starting with high-grade fluorspar (98% CaF₂) a new type of mechanical blender operates with 96% sulfuric acid and stoichiometric quantities of the two compounds which are fed to an oil fired kiln. The products are anhydrous gypsum powder and a clean hydrofluoric acid that is readily converted to the pure compound. Location of new plants near domestic sources of 72% CaF₂, fluorspar makes the anhydrous HF competitive with that made from imported raw material. Fluorine is also being recovered from phosphate rock in the wet process for phosphoric acid, the product being either sodium silico-fluoride or ammonium fluoride.²

A plant for the recovery of hydrogen chloride from a gas stream whose other components were ethane, methane, ethylene and carbon dioxide was originally designed for a maximum of 65% HCl. Present operations must take care of from 80% to 90% of this gas. The usual HCl recovery system is based on removal of this gas as a concentrated water solution constituting commercial hydrochloric acid. The final product here is a hydrogen chloride gas freed to all other compounds, which is recycled to the main process. Hence hydrogen chloride is stripped from the strong hydrochloric acid absorption product (32% to 33% HCl), and the weak acid remaining is used instead of water as the absorbent medium. The plant includes absorbers, heat exchangers, weak-acid coolers, condensers, reboilers, and a tails tower.³

Specially reactive disulfonic anthroquinone acids are being used to recover pure sulfur from hydrogen present in natural gas and coal gas. Hydrogen sulfide reacts with aqueous solutions of these acids to produce a hydroquinone and a pure sulfur precipitate. The hydroquinone is reconverted to the original anthroquinone acid by air oxidation, while the sulfur is removed with a vacuum filter. The process has been tested commercially in great

An extensive survey of chemicals used in

Britain in 1960, and reports are to the effect that it is cleaner and safer than conventional systems and that operating costs are around one-third that of the ordinary iron oxide system.⁴

Vitreous silica textile yarns are being produced for the Air Force, being drawn from a fused quartz cane in electrical heating devices, both induction and resistance units being employed. The best performance was obtained from a resistance unit shielded against radiation losses and operating on a protective atmosphere. Four-and-five filament strands were drawn, gathered, coated and accumulated on 12-inch drum. Filaments and strands were tested for strength, elongation and modulus of elasticity.⁵

METALS

Anodic protection can now be safely added to the list of corrosion-control methods, provided that close regulation is maintained of the anodic polarization curve. The six common methods of control of corrosion in chemical process industries, are as follows: Materials selection, coatings, inhibitors, nonmetallics, design, cathodic protection. Anodic protection involves a method of producing passivity by the application of an electric current, whose potential is carefully controlled by use of a reference electrode between such limits as 300 to 600 MV. Typical examples of passivity produced by chemical means include the action of the oxygen of air on freshly cleaned aluminum in which a corrosion-resistant film is formed, and dipping mild steel into concentrated nitric acid. Concrete evidence of the effectiveness of anodic corrosion control is contained in a complete account of the experience of a large oil company in connection with storage of oleum; its transportation in a tank trailer; storage of 66° Be (93%) H₂SO₄; and the protection of two large reaction vessels, one neutralizing a sulfonic acid by caustic soda, and the other a sulfonator in which an arylalkane is reacted with 100% H₂SO₄. Corrosion protection against oleum involves a platinum-clad cathode and a calomel cell with a salt bridge as a reference electrode. The trailer handling oleum is equipped with a battery-powered controller. The protection of the reaction vessels involves maintaining a very narrow range (90-125 MV) where the potential curves of the two reactants overlap. As a proof of the effectiveness of corrosion-control in the storage and handling of oleum in stainless steel, which is regarded as quite resistant to oleum, the oleum used by this particular oil company must meet the requirement of very low iron content, which is well below 100 ppm. An oleum originally containing about 50 ppm iron when stored in stainless steel without corrosion protection ranged from 460 to 1200 ppm. With the system of protection described above it remained at a range of 69 to 72 ppm. With suitable modifications depending on potentials, anodic protection appears to be capable of extension to a variety of metals and such chemicals as phosphoric acid, and solutions of

caustic soda, aluminum sulfate, sodium carbonate, and ammonium nitrate.⁶

"Embrittlement by Liquid Metals" is the title of a new book whose authors are respectively on the staffs of Army Ordnance and the Amour Research Foundation. The book includes not only a collection of a vast amount of information scattered through the technical literature but also previously unpublished results of the latest research in the field. From this material there emerges a new approach to embrittlement by liquid metals, based on modern dislocation theories of brittle fracture. The book is of interest alike to scientists working in the fields of nuclear energy, welding, soldering, brazing, mechanical testing, brittle fracture and hot deformation of metals, and to engineers engaged in the design of systems in liquid metal environments.⁷

An intermetallic compound of platinum and lithium is said to have twice the catalytic activity of supported platinum oxide. This new and highly active hydrogenation catalyst owes its origin to a laboratory accident some years ago. Lithium and lithium hydride were being heated in a platinum crucible in an atmosphere of hydrogen, the purpose being reintroduction of hydrogen lost from the heated hydride. In the resulting explosion most of the platinum crucible was destroyed and a fiercely burning mass resulted which could not be extinguished. The intermetallic compound is now made by heating freshly cut lithium in a molybdenum crucible by a resistance furnace either in a vacuum or in oxygen, and introducing a strip of platinum fused to a glass rod. At a temperature of around 550°C a violently exothermic reaction takes place. Excess lithium is removed by hydrolysis, and the remaining powder is the hydrogenation catalyst that is much more easily made than the usual platinum catalyst. The new material is regarded as having a structure in which each lithium atom has 12 platinum atoms around it, and each platinum atom has 6 lithium atoms around it, the electrons being thinly spread.⁸

NUCLEAR CHEMISTRY

Two promising applications of nuclear energy have been recently announced. One involves the production of industrial heat, without electrical generators being involved, by use of molten uranium salts. A \$4.1 million experimental plant, to be tested by the Atomic Energy Commission, is designed to produce 10,000 thermal kilowatts of heat and to operate at a higher temperature and more efficiently than with solid fuel elements. By use of molten fuel the cost of making solid fuel is cut and fuel reprocessing is simplified. The fuel is a mixture of lithium and beryllium fluorides containing dissolved uranium fluoride. The second application is the utilization of heat from a nuclear plant now under construction to make coal gas from West Virginia coal. Preheated helium will be passed through the atomic reactor, its temperature being raised to 2500°F. Helium then reacts in a heat exchanger with a mixture of preheated coal and water, the coal gas that is formed passing out from the top of the heat exchanger.⁹

The alarm felt after the announcement of the cheap method involving gas centrifuging of uranium hexafluoride to produce U-235 has somewhat subsided in the field of national defense, but there is considerable anxiety about the use of the process for enriching uranium as a reactor fuel. Instead of raising the concentration of U-235 from 0.6% to 90%, a single stage brings the value to 3% and multiple stages reach 6%, which is a satisfactory reactor fuel. The declaration by the AEC of the process as a "state secret" is disturbing, since it is

feared that West German companies will have a "head start" in commercial operations employing gas centrifuging.¹⁰

A self-luminous paint, already approved for watch dials but showing promise of still wider applications, both civilian and military, contains tritium instead of radium. The new paint is reported as having higher initial brightness, longer luminous half-life, and lower energy level than radium paint. With a maximum beta energy of 18 K.E.V., the tritium paint presents no external hazard, the radiation being too weak to penetrate a single sheet of ordinary paper. Tritium is chemically bound in the molecule of a transparent plastic and minute particles of crystalline phosphor are coated with the plastic containing H³. AEC regulations permit 25 millicuries of tritium per watch face. A vial containing 50 curies of Co⁶⁰ would require the protection of several feet of concrete.¹¹

ELECTROCHEMISTRY

Outer space operations represent the special field of applica-

cation of a new rechargeable nickel Cadmium battery. Noteworthy features are good electrical performance, a porous synthetic sheet separator to avoid oxidation even at high temperatures, and a ceramic-to-metal hermetic seal. The last named feature is said to involve a true molecular bond between ceramic and metal. The cell is rated at 5 amperes and is capable of at least 20,000 re-chargings over several years of use. The battery acts as a voltage regulator when there has been a collection of excess solar energy, thus preventing overloading of electronic circuits.¹²

Tunnel diodes were announced in 1959 in connection with areas of negative current voltage relationship were observed. A new type of "tunneling" has been observed in what is known as a "tunnel sandwich." In this cryogenic device superconducting metal films are used instead of semiconducting materials to give electron tunneling. The sandwich is made by depositing a thin film of aluminum on a nonconductive surface. The film is immediately exposed to air long enough for formation of a natural oxide layer from 10 to 100 atoms thick. If a potential is applied between the metals at temperatures as low as 10°K, tunneling takes place. Electron passage through the barrier is directly proportional to voltage even at extremely low potentials. At very low temperatures the phenomenon of "negative resistance" is observed. The power requirement for the tunnel sandwich is about 1/1000 that of a tunnel diode. Application of a magnetic field produces enormous current changes. Various practical applications are seen for the new device in the way of microminiature switches, diodes, negative resistance diodes, triodes, and capacitors, and complex circuits.¹³

The process now generally known as "plasma spray coating" subjects high-melting materials such as oxides, carbides, nitrides and metals themselves to temperatures up to 30,000°F and velocities up to 34,000 ft./sec. for the purpose of coating base materials. These need not be high melting, since even paper, plastics or wood materials have been spray coated, but usually are metals such as brass or steel as well as graphite. Heat is dissipated quickly after the molten material leaves the gun. The bonding of a plasma spray coating and the base material includes chemical transformation, metallurgical alloying, or even more mechanical interlocking. The gun is cooled by a circulating liquid and is fed by the plasma gas, usually helium or argon, fed into an arc where it meets the spray powder suspended in a carrier gas.

The plasma flame shooting from the nozzle against prepared base material is made up of free electrons, positively charged ions, and some neutral atoms that collide and produce extremely high temperatures. The powder that is fed into the plasma melts instantly, the molten particles are surrounded by the plasma stream and protected against oxidation, and are projected at high speed onto the material to be coated. The powders are usually kept in an oven heated to 180°F to 250°F for 24 hours after their plastic containers are opened and the surface to be coated is sandblasted shortly before being subjected to the plasma jet. A particular instance of plasma spray coating is the use of alumina powder in rocket motor nozzles used in test firings to permit their repeated use. There are, however, many other uses of the process. Something like 30 spraying materials are on the market out of a large number that might be used. Surfaces to be coated range from brazing fixtures and wire-draw dies, to fiber and paper fabricating rolls and electronic gear. Metals are bonded to glass or ceramics, while epoxyresins are sprayed on electrical equipment. Oxides, carbides, borides, silicides, and metals are common spray powders.¹⁴

ORGANIC CHEMISTRY

Carbon monoxide, a by-product of ammonia production, is utilized in a pilot plant to make urea by a method which appears to be industrially promising. Ammonia, carbon monoxide, and sulfur (dissolved in methanol) are introduced into an autoclave which operates continuously at 210°F and 300 psia. Urea is formed in yields of around 80%, while unreacted carbon monoxide and ammonia are recycled along with sulfur formed by oxidizing hydrogen sulfide. Sulfur recovered from hydrogen sulfide is a readily available raw material. Substitution of primary aliphatic and other amines for ammonia produces substituted ureas that may prove interesting, though there are no plans for their immediate production.¹⁵

A semi-works plant making 1,3 butylene glycol and now in operation is the prototype for a facility that is being constructed to produce 25 million pounds of this chemical yearly. The raw materials are formaldehyde and either acetaldehyde or acetone, which are made from the oxidation of hydrocarbons. This chemical's major application is as a plasticizer for polyvinyl chloride, which in turn is used in high-temperature electrical wire insulation and in furniture coverings. Other uses include dyes, printing inks, textile lubricants, and gasoline and lubricating oil additives.¹⁶

Butadiene is being made as a coproduct in the manufacture of isoprene, the starting substance of the elastomer, polyisoprene, which essentially duplicates natural rubber. Butadiene is polymerized to polybutadiene, which is an extender for polyisoprene. Butane is dehydrogenated over a chromium oxide catalyst, and butylene is recovered along with butadiene, the desired product. The butylene is mixed with isomylene and fed to vapor phase reactors, dehydrogenation to butadiene and isoprene taking place over an iron-oxide catalyst promoted with chromium oxide and potassium carbonate. The reaction takes place at 1100°F and at 10 psig pressure. A complex system of compression, scrubbing and fractionation separates the final products.¹⁷

The substitution of 95% oxygen for air in a process of non-catalytic hydrocarbons, described under Reference No. 19 in the November-December issue of the *Journal*, has now been fully covered in a journal article to which reference is made herewith. The original process based on air and the more recent process in which 95% oxygen was substituted are compared in two similar

schematic diagrams. The effect of reactant ratio on product yield in oxidation of propane is shown by two curves, one for desirable products and the other for carbon oxides, in which product yield (weight %) is plotted against hydrocarbon-to-oxygen mole ratio. The oxygen injection system used to maintain maximum plant safety is also illustrated in a simplified fashion, but an accompanying photograph of pipes and close-coupling valves for the mixing of oxygen and hydrocarbon streams shows vividly the complexity which characterizes the process. Oxygen enters a spider-shaped sparger which is held perpendicular to the hydrocarbon flow and which has holes drilled in the upstream side only. The hole area is so sized that there is a specified pressure difference between the oxygen inside the sparger and the hydrocarbon in the main line. An instrument whose function it is to activate the safety shut-down system constantly is sensitive to changes in the oxygen pressure. If the pressure differential drops to the danger level, control air pressure is released by a snap-acting controller. Immediately this control system closes oxygen valves, and opens steam and vent valves.¹⁸

Several new facilities are proposed for producing benzene from petroleum. Out of 347 million gallons of benzene produced in the United States in 1959, about 60% was derived from petroleum. The 1930 figure is expected to reach 450 million gallons with 65% coming from petroleum. Additional capacity, either under construction or planned, is reported to be in excess of 190 million barrels. The most important change in the field of benzene production outside of coke-oven operations, is the conversion of toluene to benzene. This process will shortly have a capacity for making 61 million gallons of benzene in a year, which will consume 72 million gallons of toluene. Naphthalene, originally derived entirely from coal tar, is now becoming a major petro-chemical. Capacity for production of naphthalene from petroleum now planned, is expected to nearly equal the amount recovered from coal-tar sources in 1959. Xylenes are obtained along with benzene and toluene by extraction from catalytic reforming streams. Out of some 240 million gallons so produced in 1959, about 44% entered the fuel market. Some 64 million gallons went into solvents, and less than one half this quantity was separated into the three isomers and was sold on the chemical market.^{19, 20}

RUBBERS AND RESINS

Synthetic rubber latex has until recently, been un-

able to compete with natural rubber in the field of foam rubber articles production. A free flowing latex with 65% solids concentration is required. Such a concentration of synthetic rubber in a latex produces a putty-like semi-solid. Recently, by treatment of small synthetic rubber particles with polyvinyl methyl ether, small particle latex is concurrently dehydrated and agglomerated at 105°F and under 28-inch mercury, a dilute solution of PVM and an electrolyte being employed. Agglomeration stops at a 65% concentration, but removal of water continues to a 70% value. The particle size has increased from 600 Angstroms to 2500 Å, which renders the latex fully competitive with that of natural rubber.²¹

Polyurethane foam production is expanding so rapidly that isocyanate capacity is expected to be doubled within a year. Foam output of this type for 1960 is expected to reach 100 million pounds, which is a 30% increase over 1959 and ten times the 1956 figure. About 85% of all polyurethane foam is flexible and is mainly of the polyether type. The principal outlet for flexible foam is in the furniture industry, but the automobile industry uses about half as much as the principal consumer. A poten-

NATIONAL PARKS

(Continued from page 17)

Muir's graphic description has withstood the test of time, and visitors to the park confess their loss for words in describing the dazzling, majestic beauty of its waterfalls, groves of giant sequoias, lakes, streams and the resplendent snowfields of the High Sierras.

The eastern section of the United States, too, has national parks that attract millions of visitors every year.

In the north, Acadia National Park, Maine, recorded 1,638,000 visits and 102,516 camp-use days at its two campgrounds which contain 445 campsites. Surrounded by the sea, Acadia's 41,634 acres are dominated by the bold range of the Mount Desert Mountains. Although battered by time and ice erosion, it still remains the highest point on the Atlantic Coast.

Farther south we have Great Smoky Mountains National Park, North Carolina-Tennessee, which reported 4,528,000 visits, and a total of 442,378 camp-use days for 1960. The park embraces some 800 square miles of mountain wilderness and contains 23 campgrounds with 1,200 campsites. Many of the parks in the Great Smoky Mountains, rising to more than 6,000 feet, are enveloped by a great variety of trees, shrubs and herbs nour-

ished by rains and rushing streams. Visitors hiking on its winding trails or camping in its forests have a chance to view some of the most luxurious plant life in North America.

Our southernmost area, Everglades National Park, Florida, which reported 579,200 visits and a total of 18,724 camp-use days for 1960, offers a mosaic of highly interesting features strongly influenced by the semi-tropical climate. The park contains two modern campgrounds with a total of 106 campsites, with the heaviest use occurring during the winter months. In the Flamingo area where one of the campgrounds is located, the National Park Service has developed a modern marina with launching ramp and hoist, and dockage for boats up to 60 feet in length. Flamingo is a mecca for sport fishermen, boatmen and nature lovers.

The areas mentioned will give an idea of what the 29 national parks and the 147 other areas have to offer. Purely recreation-minded folks will prefer the recreation areas, but lovers of nature, students of history and science will vacation in or near wilderness areas, battlefield sites, or areas containing geological and archeological features.

Every American has a stake in the National Park System, and everybody should make an effort to see and enjoy these areas and know their country better.



An empty camp. Visitors have been lured by the surf for a swim and are visible in the distance.



Living it up and seeing the very best of Great Smoky Mountains National Park, North Carolina-Tennessee, economically and with utmost satisfaction.

tial market whose development will depend on radical changes in technology is in the manufacture of mattresses. Flexible clothing interliners represent a small but important outlet, which might well have important military applications. Rigid foams of the polyurethane type were turned out to the extent of 14 million pounds in 1960, but greatly accelerated production is expected. Uses which are expected to be very much expanded, include appliances, cold storage equipment, pipe ducting, industrial storage rooms, building panels, and flotation material in boats.²⁴

The first full-scale production run was made late in 1960 by a plant producing the new polycarbonate resins. This climaxed an outlay of \$11 million for research, development, and facilities, the plant being designed for an annual output of 5 million pounds. The starting substance which this plant utilizes is bisphenol-A whose formula is $(CH_3)_2C(C_6H_4OH)_2$. When reacted with phosgene $COCl_2$ hydrogen chloride is split out and taken up by pyridine. The resulting polycarbonate unit is $[OC_6H_4C(CH_3)_2C_6H_4OC_6]$. Another process now in use by a German firm operating through an American subsidiary depends on ester exchange between a carbonate diester and a dihydroxy aromatic compound. These new

resins may be fabricated by practically all plastics technologies, and have high impact strength, good heat resistance, exceptional dimensional stability and good electrical properties.²⁵

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WITH THE CHEMICAL CORPS



General Creasy and General Marshall.



Discussing radiological fallout wind vector analysis during a recent visit to Headquarters, I Corps (Group) are (from left) Colonels: Carl V. Burke, USAFRCAC Chemical chief; Raymond C. Morris, outgoing EUSA chemical officer,

and Frank M. Arthur, new EUSA chemical chief. Host for the group at Camp Red Cloud, near Uijongbu, Korea, is Lt. Col. Albert H. Voegeli, Corps' Chemical Officer (right center) and his assistant, Capt. George F. Carroll.

Dr. LeRoy D. Fothergill, left, Scientific Advisor to the U. S. Army Biological Laboratories, Fort Detrick, Frederick, Maryland, was awarded the Army's Outstanding Performance Award by Colonel Carl S. Casto, Commanding Officer, for his accomplishments in the program of the Chemical Corps at Fort Detrick.



SENIOR FIRST ARMY RESERVE CHEMICAL OFFICER RETIRES

A retirement dinner was recently held at the Seventh Regiment Armory in New York City to commemorate the retirement of Brigadier General Theodore H. Marshall, Senior Reserve Chemical Officer of the First U.S. Army. For the past five years General Marshall had been responsible for the training and administration of Chemical Corps Mobilization Detachment #10 with headquarters at 290 Broadway.

General Marshall entered on active duty with the Chemical Corps in March 1941 as a Captain in the Reserves. Prior to this Country's entry in World War II General Marshall was responsible for the co-ordination of construction of new plants at Edgewood Arsenal. He later was in charge of a pilot plant designed for incendiary bomb plants and later became Chief of Production, Engineering and Chemical Engineering for the Chemical Warfare Service Arsenals.

After his World War II service he was associated with the Lederle Laboratories Division of the American Cyanamid Company where he served as Chief Engineer of overseas operations in the International Division.

Since 1957 to the present, General Marshall has served as consultant to the U.S. Army Chemical Corps, Harvey Engineering Associates and Food Machinery and Chemical Corporation. In addition, he maintains a large, productive turkey farm on the eastern shore of Maryland.

COL. SHAPIRA AT BENNING

Lt. Col. Norman I. Shapira of Boston, Mass., has been named chairman of the Chemical Committee, U. S. Army Infantry School Command and Staff Department at Fort Benning.

A 1941 graduate of Massachusetts Institute of Technology, he attended The Infantry School's officer advanced course in 1944 and airborne course in 1950.

Colonel and Mrs. Shapira, the former Nini Dreossi of Torino, Italy, have 10 children.

Colonel Shapira has been economics officer at the Allied Commission and American Embassy in Rome, Italy.

Colonel Shapira also is a graduate of the U.S. Army Chemical School; nuclear weapons employment course and associate course, Command and General Staff College; School of Land-Air Warfare, England, and the advanced military skiing course, Italian Army Alpine School.

MILITARY ASSIGNMENTS

April 1961

Lt. Colonels

D. Coburn	USAREUR
E. G. Halligan	Army Cml Ctr, Md.
G. C. Kirt Ney	USAREUR
W. E. Stemple	Germany
E. C. Wright	CmlC Board, Md.

Majors

P. H. Donahue	USAREUR
D. H. Taylor	USAREUR

Captains

W. H. Eaton	Korea
A. H. Monshower, Jr.	USAREUR
J. H. Perkins	USAREUR
H. A. Ritscher	Korea
S. Sanders	USAREUR

Lieutenants

G. J. Altom	Ft. McClellan, Ala.
J. C. Barrett	Ft. Bragg, N. Carolina
J. T. Beckham	Ft. McClellan, Ala.
W. C. Blatchley	CmlC Board, Md.
T. J. Boliew	Ft. McClellan, Ala.
R. H. Breedlove	Ft. McClellan, Ala.
J. K. Camper	Tooele Ord. Depot, Utah
B. D. Carlson	Ft. Bragg, N. Carolina
M. J. Fiebke, Jr.	Ft. Meade, Md.
W. R. Heise	Ft. McClellan, Ala.
J. N. Hubbell, Jr.	Dugway, Utah
R. J. Hull	Ft. McClellan, Ala.
J. Koslowich	Ft. Meade, Md.
H. M. McDowell	Ft. Meade, Md.
R. C. Mitchell	Ft. McClellan, Ala.
L. R. Nunnally	Dugway, Utah
J. E. Rahe, Jr.	Ft. McClellan, Ala.
A. E. Riley	Ft. Bragg, N. Carolina
R. J. Schultz	CmlC Board, Md.
H. K. Scott	Ft. McClellan, Ala.
K. E. Simmons	Ft. McClellan, Ala.
D. E. Smith	Ft. McClellan, Ala.
S. E. Smith	Ft. McClellan, Ala.
W. L. Smith	CmlC Fld. Reqt. Agy., Ala.
J. T. Studky	Ft. McClellan, Ala.
C. G. Unger	Ft. McClellan, Ala.
R. D. Wade	Ft. McClellan, Ala.
J. J. Waldron	Ft. McClellan, Ala.
R. Y. Wyrick	Ft. McClellan, Ala.

Retirements

Maj. G. M. Casebeer	USAREUR
Capt. O. L. Sewell	Ft. McClellan, Ala.

Relieved From Active Duty

Lt. K. L. Frederick	Ft. Campbell, Ky.
Lt. J. W. Gilliland, Jr.	Army Cml Ctr, Md.
Lt. R. A. Hosfeld	Ft. Lewis, Wash.
Lt. G. J. Jobczynski	Army Cml Ctr, Md.
Lt. J. R. Kirk	Ft. Leonard Wood, Mo.
Lt. W. W. Nowotny, Jr.	Ft. Bragg, N. Carolina
Lt. T. C. Wallace	Dugway, Utah

DISTINGUISHED GRADUATE: SFC (E6) Gene R. Dollarhide, 2d Missile Battalion, 333d Artillery, receiving Armed Forces Chemical Association Medallion from Lt. Colonel William J. Owens, Commanding Officer, 1st Medium Tank Battalion, 37th Armor at Graduation Ceremony, Combined Arms School, 7th Army, Germany. Lt. Colonel Vernon Dehner, Chief CBR Section observing the presentation.



First Lt. Robert J. Gabrielli, 3d Ms 1 Bn, 21st Arty Distinguished Graduate of CBR Class #6, Combined Arms School, Seventh Army Training Center, Germany, receiving Armed Forces Chemical Association Medallion from Colonel R. D. Chapman, Seventh Army Chemical Officer. Lt. Col. Vernon Dehner, Chief, CBR Section observing.

Presentation of two Armed Forces Chemical Association Medallions to Distinguished Graduates of CBR Officer Course #7. L. to R.—Lt. Col. Carl G. Witte, Assistant Commandant, Combined Arms School, 7th Army, Germany, 2d Lt. Granville S. Knox, Jr., 1st Obn Bn, 26th Arty, 1st Lt. Leonard P. Wishart III, 1st Battle Group, 34th Infantry.



HIGHEST CIVILIAN AWARD—Mr. Lester J. Conkling (center), Technical Advisor to the Commanding Officer, Edgewood Arsenal, displays his second award of the highest award a civilian may receive from the Army, the Decoration for Exceptional Civilian Service. With him are (left) Maj. Gen. Marshall Stubbs, Chief Chemical Officer, who made the presentation, and Brig. Gen. Graydon C. Essman (right), Commanding General, Army Chemical Center, Md.

PEOPLE

(Continued from page 11)

(Continued from page 21)

been appointed General Sales Manager of the Newport Industries Division of Heyden Newport Chemical Corporation. Heyden Newport announces five organizational changes in the sales structure of the Heyden Chemical Division: **F. A. Degener** has been appointed Director of Marketing. **W. C. Deakyne, Jr.**, assumes the post of General Sales Manager; and **James Claypoole** becomes Field Sales Manager; **E. L. Barkley**, appointed to Manager of Sales Development, and **E. M. Vogel** to District Sales Manager, New York and New Jersey. Monsanto Chemical Company's Inorganic Chemicals Division announces several changes in its marketing staff: **Donald Dunwody**, appointed executive sales specialist for the West Coast; he is succeeded at San Francisco by **Andrew L. Smith**; and **Donald W. Witt** succeeds Smith at Los Angeles; **J. C. Pate**, sales representative at Boston, has been transferred to the Los Angeles sales group; **David Sliney**, sales trainee at St. Louis, has been transferred to Chicago as a sales representative; **Robert C. Bosworth**, sales representative at St. Louis, has been appointed sales supervisor of calcium and industrial phosphates at St. Louis, replacing **Allan F. Davis**, who transferred to the company's Agricultural Chemicals Division. **W. P. Brashear**, United States Borax & Chemical Corp. sales representative, has been transferred from Sulphur Springs, Texas, to Madison, Wis. **Paul E. Broderick**, vice-president of Electro-Science Investors, Inc., Palo Alto, has also been appointed treasurer of Knapic Electro-Physics, Inc. **James E. Cameron** was named comptroller and assistant treasurer. **Maj. Gen. Albert Boyd**, Westinghouse Electric Corp. vice-president and general manager of its defense products divisions (Baltimore, Md.) has been honored with the company's highest award—the Order of Merit. **George Sarvis** has been promoted to manager of the Armed Forces and Export Division of Lever Brothers Company; **Edmund Nolan, Jr.**, has been appointed Armed Forces Department manager. **Hugo Riemer**, former executive vice-president, has been elected president of United States Borax & Chemical Corporation. **James M. Gerstley**, former president, has been named vice chairman of the board. **Dr. Helmuth W. Schultz** has been appointed Manager, Catalysts, for Nuodex Products Division, Heyden Newport Chemical Corporation. **James C. Sheehan** has been named a product line manager at Mine Safety Appliances Company, Pittsburgh; he served during World War II as a lieutenant with the U.S. Army Air Corps. **Kenneth C. Loughlin** has announced his retirement as President of Celanese Corporation of America, after 32 years of service with the Corporation; a native of Wilmington, North Carolina, with a B.S. degree from North Carolina State College, Mr. Loughlin joined Celanese in 1929; his initial laboratory and sales work was followed by 19 years of service as southern district sales manager. **Dr. Richard E. Farrar** has been appointed to the newly-created position of Manager-Research Coordination for Colgate-Palmolive Company's Household Products Division. **Eldon E. Fox** has joined the staff of Malcolm P. Ferguson, president of The Bendix Corporation, to become director of advertising and public relations after the retirement of **William A. Mara** within the next several months. **W. B. Bryan** has been appointed as advertising manager of the 20 Mule Team Products department of U. S. Borax & Chemical Corp. **Robert E. Cochran** has been named assistant manager of sales for the Chlor-Alkali Division of Food Machinery and Chemical Corporation; formerly alkali product manager, he will be replaced by **Richard M. Hover**.

CHEMICAL BATTALION TESTS NEW SMOKE CONCEPTS AT DUGWAY

Lt. Col. Lowell E. Thompson, Commanding Officer, 2nd Chemical Battalion, Dugway Proving Grounds, has announced that a proposal to reorganize Smoke Generator Units for "greater mobility" is being staffed at the Chemical Battalion headquarters. The finished proposal will be forwarded to the U.S. Army Chemical Board, Army Chemical Center, Maryland.

According to Captain Joseph I. McLean, Battalion Executive Officer, "The proposal will enable combat arms to employ Smoke Generator Units to greater advantage than at the present time. Smoke Generators will be able to provide concealment for mobile forces under new concepts of warfare."

At present, two smoke generators are carried on a $\frac{1}{2}$ -ton trailer. Fog oil in 55-gallon drums is delivered to each generator by $2\frac{1}{2}$ -ton trucks. Next, jeeps towing trailers with two generators in each trailer move along the smoke line and the generators are lowered into designated positions.

Fuel supply personnel drive 2½-ton trucks down the smoke line and deposit oil drums at each generator. Generator operators open the drums, insert fuel lines and prepare to start the smoke producing machines.

If the smoke line must be shifted, fuel lines are disconnected and jeeps move down the line to collect the generators. Fuel supply personnel must then move along the old line to pick up the oil drums.

The new concept is basically to mount a smoke generator in the jeep and a 55-gallon drum of fuel in a trailer. Jeeps are driven to selected positions and, still mounted, the generators are ready for use. If the smoke line requires movement, jeeps can easily move to a new position. Oil would be replenished by a tank truck.

The fact that generator and oil drums are not man-handled under these concepts improves operation and reduces cost. Lost or damaged equipment and personnel injuries are reduced when a unit moves in darkness or adverse weather conditions.

Colonel Thompson said in conclusion: "The advantages of providing concealment with a smoke generating unit are innumerable. If approved, I feel that an entirely new concept in combat tactics could develop."

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A. F. C. A. AFFAIRS

16TH ANNUAL MEETING

Plans for the 16th Annual Meeting of the Armed Forces Chemical Association are beginning to take shape under the guidance of Carroll W. Hayes of Celanese.

Theme for the meeting is "Balanced Military Power through Science and Industry." The meeting is to be held in the Statler Hotel, Washington, September 13-14-15. Actual meeting sessions will take place on the 14-15 September.

The Army is acting as host this year and the format calls for technical presentations as well as the broader phases of chemical problems.

NEW YORK CHAPTER

Mr. Joel Henry, Secretary-Treasurer of the New York Chapter of the Armed Forces Chemical Association reports the Chapter has increased the membership by seven. They are: Beckman Instruments, Inc., Fullerton, Cal.; Booz-Allen Applied Research, Inc., Bethesda, Md.; First National City Bank, New York, N.Y.; Hoffman-La Roche, Inc., New Jersey; Millmaster Chemical Corporation, New York, N.Y.; The Chase Manhattan Bank, New York, N.Y.

THE CHEMISTS' CLUB ELECTS GENERAL CREASY

The election of Maj. Gen. William M. Creasy, USA (Ret.) to its Board of Trustees has been announced by the Chemists' Club of New York. He will fill out the unexpired term of Mr. Roland Soule who has retired.

General Creasy is best known for his service as Chief Chemical Officer of the U.S. Army during the period of 1946 to 1958. The position of Chief Chemical Officer was part of top management structure of the Department of the Army. Period preceding this appointment fell generally into three phases, i.e., general military development, research, development, engineering and production, and management of total research and development activities at Department of the Army and Chemical Corps levels. Previous experience included general engineering, manufacturing, procurement, supply, distribution, maintenance, training, education, scientific intelligence and military field operations.

After graduation from West Point, General Creasy took specialized training in the Chemical Warfare School and professional engineering training at MIT. This specialized training was put to excellent use in the direction and management of the working force of 22,000 people making up the U.S. Army Chemical Corps.

On retirement from the Army, General Creasy became Vice President of the Lummus Company where he is charged with the direction and operation of the New York Division and reports directly to the President.



CHESAPEAKE CHAPTER

The Chesapeake Chapter of the Armed Forces Chemical Association held its second meeting of the season, in mid-January, at Fort George G. Meade.

The tour and meeting, designed to familiarize members of the association with various phases of Army operations, was concerned with the defense of Continental United States from Air Attack.

Hosting the professional group, many of whom are Army Chemical Center personnel, was the 35th Brigade (Artillery) which conducted a tour of the Missile Master Control Center. This included a briefing of how we are protected from air attack around the clock.

At the dinner meeting Mr. H. W. Chitty, Chief of Technical Operations, U.S. Army Signal Air Defense Engineering Agency, discussed the work of the agency. This was followed by a film, "Seconds for Survival."

CARBON CONFERENCE AT PENN STATE

The fifth biennial conference on carbon will be held at The Pennsylvania State University June 19-23, 1961, under the co-sponsorship of the University and the American Carbon Committee.

Eighty-five papers from research laboratories throughout the world will be given in the following general areas: kinetics and surface physics, dislocations and high temperature properties, electronic properties, radiation effects, pyrolytic graphites, processing and graphitization, structural studies, adsorption and surface chemistry, and uses and applications.

The American Carbon Committee is comprised of representatives of research organizations and industries in the field. It has foreign correspondants in Belgium, France, Germany, Japan and the United Kingdom.

G. R. Hennig, of Argonne National Laboratory, is program chairman for the conference. Philip L. Walker, Jr., of Penn State, is local chairman.

NIKE ZEUS

At White Sands Missile Range, New Mexico, the Department of the Army has initiated an eight-week course to train NIKE ZEUS test personnel for future phases of the Army's anti-missile missile development program. Army military and civilian personnel will be trained in missile handling and firing techniques, and in the operation of the electronic brains designed to guide the Army's NIKE ZEUS to intercept attacking intercontinental ballistic missiles.

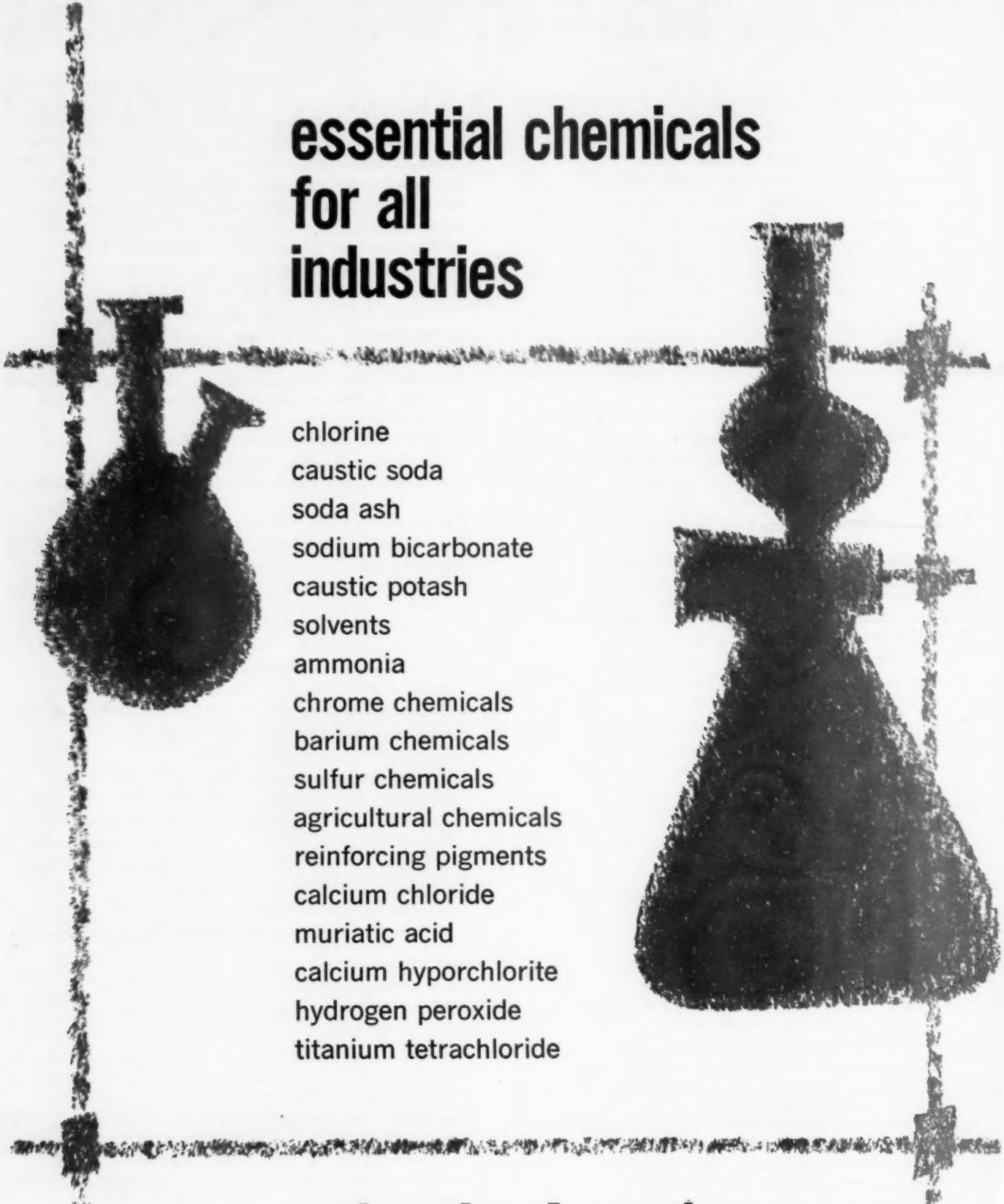
The school is conducted by the Army Rocket and Guided Missile Agency, technical supervisor of the NIKE ZEUS development program. The instructors come from the U.S. Army Ordnance Special Weapons and Ammunition Command, Picatinny Arsenal, Dover, New Jersey, and the Western Electric Company, prime contractor for NIKE ZEUS.

GROUP AND SUSTAINING MEMBERS

OF THE ARMED FORCES CHEMICAL ASSOCIATION

- Abbott Laboratories, North Chicago, Ill.
Adache Associates, Inc., Engineers, Cleveland, Ohio
Aerojet General Corporation, Downey, Calif.
Aircraft Armaments, Inc., Cockeysville, Md.
Air Reduction Company, Inc., New York, N.Y.
Allied Chemical Corporation, New York, N.Y.
American Cyanamid Company, New York, N.Y.
American Potash & Chemical Corporation, 300 West Sixth, St., Los Angeles 54, California
American Zinc, Lead & Smelting Co., St. Louis, Mo.
Analytic Services, Inc., 5202 Leesburg Pike, Alexandria, Va.
Armstrong Cork Company, Lancaster, Pa.
Astra Pharmaceutical Products, Inc., Worcester 6, Mass.
Atlas Powder Company, Wilmington, Del.
Avco Corporation, 750 Third Ave., New York 17, N.Y.
Barnebey-Cheney Company, Columbus, Ohio
Bechtel Corporation, San Francisco, Calif.
Beckman Instruments, Inc., 2500 Harbor Boulevard, Fullerton, Calif.
Blaw-Knox Company, Pittsburgh, Pa.
Booz-Allen Applied Research, Inc., 4921 Auburn Ave., Bethesda, Md.
Brothers Chemical Company, 575 Forest St., Orange, N.J.
Brown Company, 150 Causeway St., Boston, Mass.
Casco Products Corporation, Bridgeport, Conn.
Celanese Corporation of America, New York, N.Y.
City Chemical Corp., New York, N.Y.
Columbia-Southern Chemical Corporation, Division of Pittsburgh Plate Glass Company, Pittsburgh 22, Penna.
Commercial Solvents Corporation, New York 16, N.Y.
Continental Oil Co., Ponca City, Okla.
Controls for Radiation, Inc., 130 Alewife Brook Parkway, Cambridge 40, Mass.
Diamond Alkali Company, Cleveland, Ohio
Dow Chemical Company, Midland, Mich.
E. I. duPont de Nemours & Co., Inc., Wilmington, Del.
Edo Corporation, College Point, N.Y.
Engelhard Industries, Newark, N.J.
Esso Research and Engineering Co., Linden, N.J.
Ethyl Corporation, Baton Rouge, La.
Evans Research & Development Corp., New York, N.Y.
Federal Laboratories, Inc., Saltsburg, Pa.
Ferguson, H. K., Company, The, Cleveland, Ohio
Ferro Corporation, Cleveland, Ohio
Firestone Rubber and Latex Division of Firestone Tire & Rubber Co., Fall River, Mass.
First National City Bank, 55 Wall St., New York 15, N.Y.
Fisher Price Toys, Inc., East Aurora, N.Y.
Fisher Scientific Co., New York, N.Y.
Fluor Corporation, Ltd., The, Whittier, Calif.
Food Machinery & Chemical Corporation, New York, N.Y.
Fraser & Johnston Co., San Francisco, Calif.
General Aniline & Film Corporation, New York, N.Y.
General Electric Company, Chemical & Metallurgical Division, Bridgeport, Conn.
General Tire & Rubber Company, The, Wabash, Ind.
Goodrich, B. F., Chemical Company, Cleveland, Ohio
Harshaw Chemical Company, The, Cleveland, Ohio
Harvey Aluminum, Torrance, Calif.
Hercules Powder Company, Wilmington, Del.
Heyden Newport Chemical Corporation, New York, N.Y.
Hoffman-La Roche, Inc., Nutley 10, N.J.
Hooker Chemical Corporation, Niagara Falls, N.Y.
Industrial Rubber Goods Company, St. Joseph, Mich.
International Nickel Co., Inc., New York, N.Y.
International Salt Co., Inc., Scranton, Pa.
Kennecott Copper Corporation, New York, N.Y.
Koppers Company, Inc., Pittsburgh, Pa.
Lambert-Hudnut Mfg., Laboratories, Inc., Lititz, Penna. subsidiary of Warner-Lambert Pharmaceutical Company, St. Louis, Mo.
Eli Lilly and Co., Indianapolis 6, Ind.
Little, Arthur D., Inc., Cambridge, Mass.
Lummus Company, The, 385 Madison Ave., New York, 17, N.Y.
The Martin Company, Baltimore 3, Md.
Melpar, Incorporated, 3000 Arlington Blvd., Falls Church, Va.
Merck & Company, Inc., Rahway, N.J.
Millmaster Chemical Corporation, 99 Park Ave., New York 16, N.Y.
Mine Safety Appliances Co., Pittsburgh, Pa.
Monsanto Chemical Company, St. Louis, Mo.
National Lead Co., 111 Broadway, New York 6, N.Y.
Niagara Blower Co., New York, N.Y.
Olin Mathieson Chemical Corp., 10 Light St., Baltimore, Md.
Oronite Chemical Company, San Francisco, Calif.
Pemco Corporation, Baltimore, Md.
Pennsalt Chemicals Corporation, Philadelphia, Pa.
Pfizer, Chas. & Company, Inc., Brooklyn, N.Y.
Pfaudler Company, a Division of Pfaudler Permutit, Inc., Rochester 3, New York
Phillips Petroleum Company, Bartlesville, Okla.
Pittsburgh Chemical Co., Pittsburgh, Pa.
Procter & Gamble, Cincinnati, Ohio.
Riegel Paper Corporation, 260 Madison Ave., New York 16, N.Y.
Shell Chemical Corp., Denver, Colo.
Shell Development Company, Emeryville, Calif.
Sheller Mfg. Co., Dryden Rubber Div., Chicago, Ill.
Shwayder Bros., Inc., Denver, Colo.
Standard Oil Company (Indiana), Chicago, Ill.
Stauffer Chemical Company, New York, N.Y.
Sun Oil Company, Philadelphia, Pa.
The Chase Manhattan Bank, 20 Pine Street, New York, N.Y.
Union Carbide Corporation, New York, N.Y.
United-Carr Fastener Corp., Cambridge, Mass.
United States Borax & Chemical Corp., 630 Shatto Place, Los Angeles 5, Calif.
Universal Match Corp., Ferguson, Mo.
Vitro Corporation of America, New York, N.Y.
Vulcan-Cincinnati, Inc., 120 Sycamore St., Cincinnati 2, Ohio
Wigton-Abbott Corporation, 1225 South Avenue, Plainfield, N.J.
Wyandotte Chemicals Corp., Wyandotte, Mich.

essential chemicals for all industries



chlorine
caustic soda
soda ash
sodium bicarbonate
caustic potash
solvents
ammonia
chrome chemicals
barium chemicals
sulfur chemicals
agricultural chemicals
reinforcing pigments
calcium chloride
muriatic acid
calcium hypochlorite
hydrogen peroxide
titanium tetrachloride

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COLUMBIA-SOUTHERN CHEMICAL CORPORATION
A Subsidiary of Pittsburgh Plate Glass Company
One Gateway Center, Pittsburgh 22, Pennsylvania